CONTRACT NAS8-31844

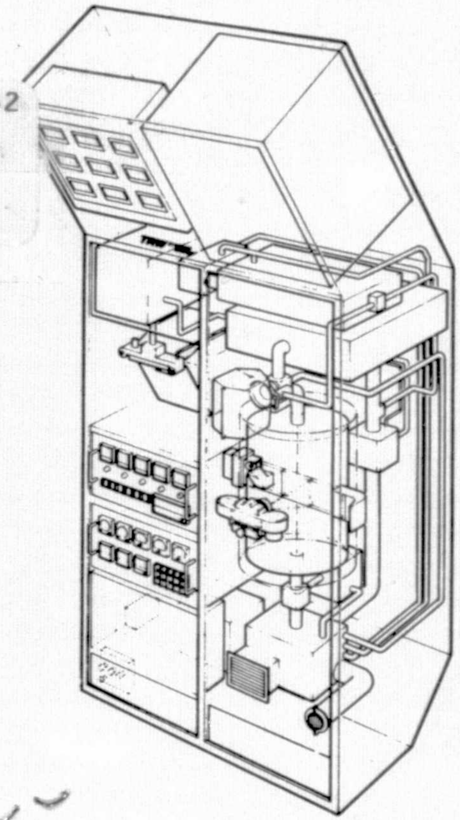
PHASE B-FINAL DEFINITION AND PRELIMINARY DESIGN STUDY FOR THE INITIAL ATMOSPHERIC CLOUD PHYSICS LABORATORY (ACPL) - A Spacelab Mission Payload

ORIENTATION MEETING (DR-MA-03)

(NASA-CR-144170) PHASE B: FINAL DEFINITION AND PRELIMINARY DESIGN STUDY FOR THE INITIAL ATMOSPHERIC CLOUD PHYSICS LABORATORY (ACPL): A SPACELAB MISSION PAYLOAD (TRW SYSTEMS GROUP) 100 p HC $5.00 CSCL 22B G3/18

N76-25332

UNCLAS 42855



JANUARY 27, 1976

Prepared for

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
GEORGE C. MARSHALL SPACE FLIGHT CENTER
Marshall Space Flight Center, Alabama 35812

By

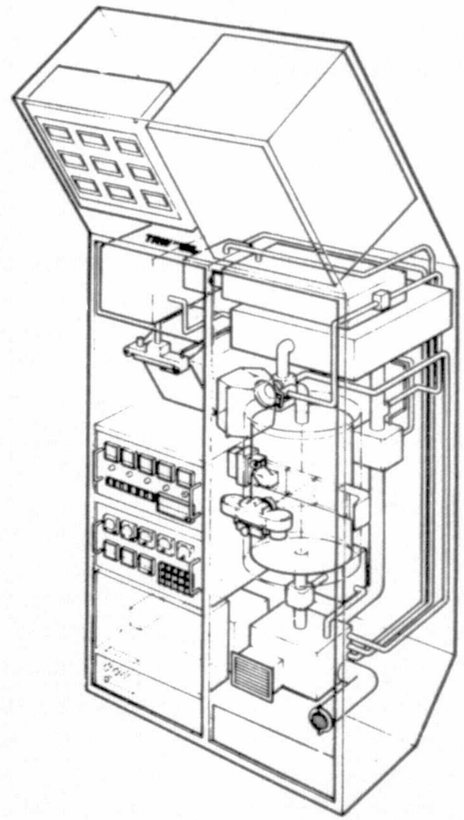
ACPL PROGRAM TEAM
O.W. Clausen, Program Manager

TRW
SYSTEMS GROUP
ONE SPACE PARK • REDONDO BEACH • CALIFORNIA 90278

CONTRACT NAS8-31844

PHASE B-FINAL DEFINITION AND PRELIMINARY DESIGN STUDY FOR THE INITIAL ATMOSPHERIC CLOUD PHYSICS LABORATORY (ACPL) - A Spacelab Mission Payload

ORIENTATION MEETING (DR-MA-03)



JANUARY 27, 1976

Prepared for

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
GEORGE C. MARSHALL SPACE FLIGHT CENTER
Marshall Space Flight Center, Alabama 35812

By

ACPL PROGRAM TEAM
O.W. Clausen, Program Manager

TRW
SYSTEMS GROUP
ONE SPACE PARK • REDONDO BEACH • CALIFORNIA 90278

AGENDA

NASA REMARKS

TRW INTRODUCTION

REPRESENTATIVE DESIGN CONCEPT

- SYSTEM CONFIGURATION AND TRADES
- MISSION OPERATIONS
- SUBSYSTEM CONFIGURATION AND TRADES

STUDY PLAN OVERVIEW

MISSION OPERATIONS (GRUMMAN)

LUNCH

SCIENTIFIC REQUIREMENTS

TRW
SYSTEMS GROUP

INTRODUCTION

BILL CLAUSEN

PRECEDING PAGE BLANK NOT FILMED

TRW
SYSTEMS GROUP

The end objective of the Atmospheric Cloud Physics Laboratory (ACPL) program, is to provide a low cost multi-purpose facility for use by the science community to conduct significant cloud physics experiments in a zero gravity environment. As a facility, it must be capable of performing a wide range of experiments and of evolving with time to meet the changing needs of the science. This Phase B Study is a vital step in the development, production and operation of ACPL. TRW is enthusiastic about the potential of the program to advance mans ability to predict and/or modify weather and is excited to be a part of this extremely important activity.

GENERAL OBJECTIVE: TO SIGNIFICANTLY INCREASE THE LEVEL OF KNOWLEDGE OF ATMOSPHERIC CLOUD MICROPHYSICAL PROCESSES

PROJECT OBJECTIVES: TO PROVIDE SCIENCE COMMUNITY WITH MULTI-PURPOSE LABORATORY FACILITY TO CONDUCT FUNDAMENTAL EXPERIMENTAL STUDIES OF WARM AND COLD CLOUD PROCESSES IN ZERO GRAVITY

STUDY OBJECTIVES: FINAL DEFINITION AND PRELIMINARY DESIGN OF LABORATORY TO PROVIDE FIRM BASIS FOR SUBSEQUENT HARDWARE DEVELOPMENT, PRODUCTION AND OPERATION

TRW
SYSTEMS GROUP

Achieving the general project and specific study objectives requires that the Atmospheric Cloud Physics Laboratory (ACPL) design have the following three major characteristics:

- Capable of evolutionary growth to meet the needs of increasingly complex experiments.
- Flexibility to accommodate a wide range of experiment classes.
- Minimum cost to maximize the flight opportunities within the available resources.

These characteristics translate into the key program guidelines shown on the facing page.

KEY PROGRAM GUIDELINES

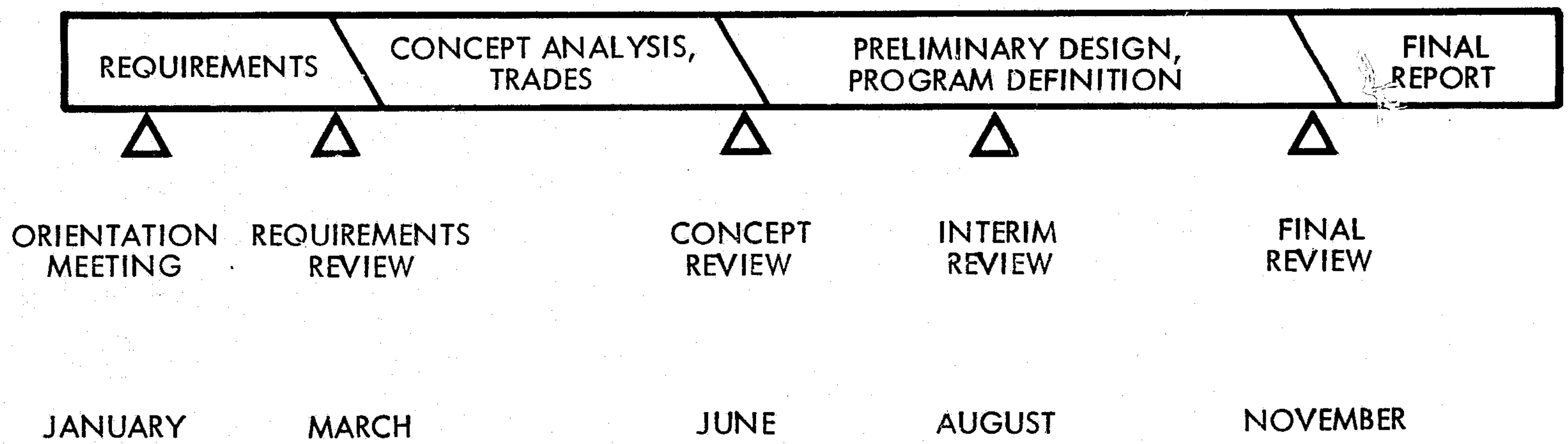
- DESIGN FLEXIBILITY TO ACCOMMODATE EVOLUTIONARY GROWTH AND NEW TECHNOLOGY ADVANCES
- MAXIMUM USE OF GROUND-BASED LABORATORY EXPERIENCE
- SIGNIFICANT USE OF COMMERCIAL EQUIPMENT MODIFIED AS NECESSARY TO FUNCTION IN THE SPACELAB ENVIRONMENT
- MAXIMUM UTILIZATION OF SPACELAB SUPPORT SUBSYSTEMS AND COMMON EQUIPMENT

TRW
SYSTEMS GROUP

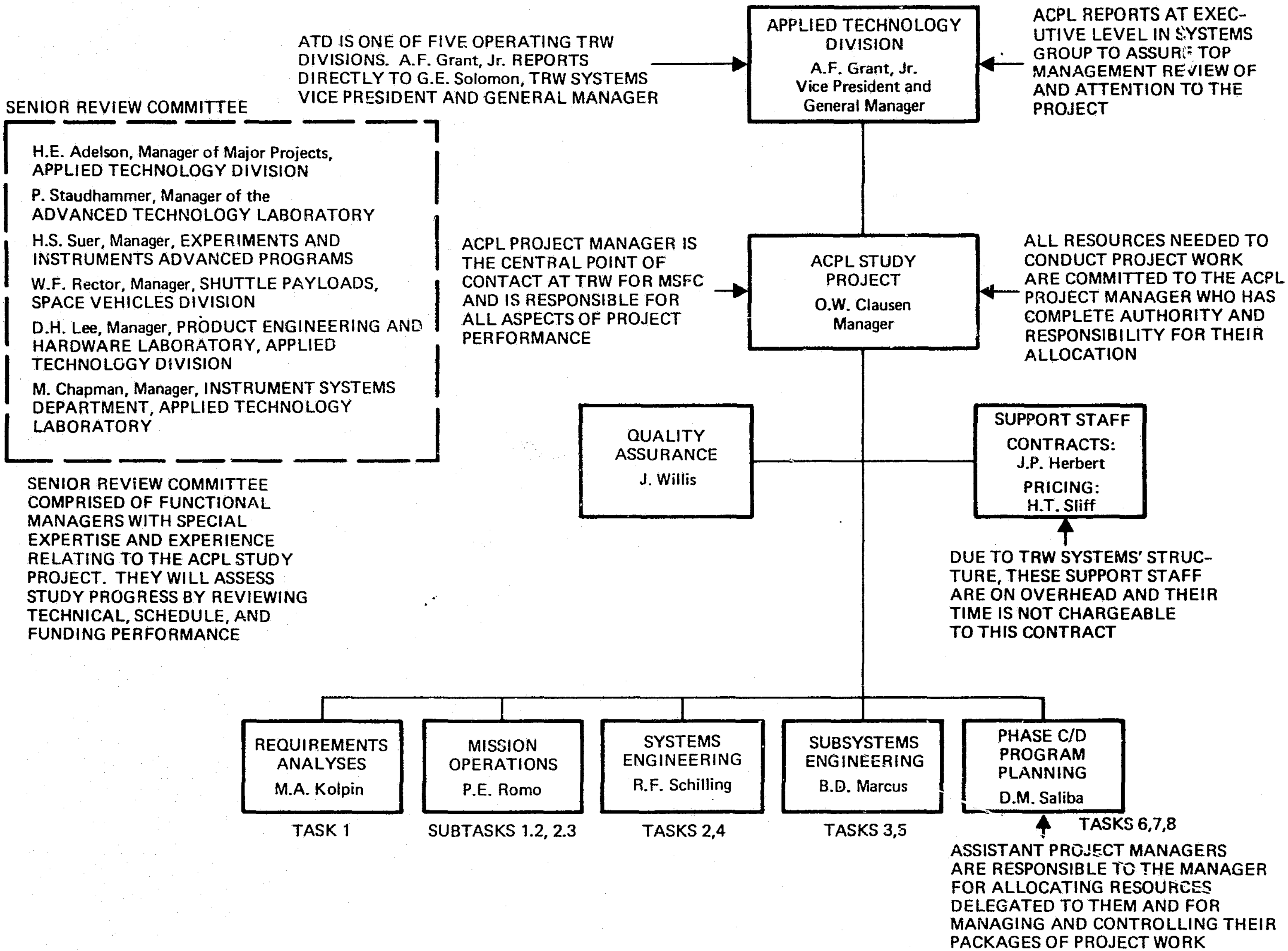
The ACPL Phase B study is divided into four major elements as shown on facing page. Five major reviews are scheduled as follows:

Orientation Meeting:	14 days
Requirements Review:	2 months
Concept Review:	5 1/2 months
Interim Review:	7 1/2 months
Final Review:	10 months

ACPL PHASE B STUDY PHASING AND REVIEWS



The TRW Systems Phase B Study Organization is shown on the facing page. Project manager will be advised by Senior Reviewers with special expertise and experience relating to the ACPL study.



Project Organization and Key Personnel

TRW
SYSTEMS GROUP

SYSTEMS ENGINEERING

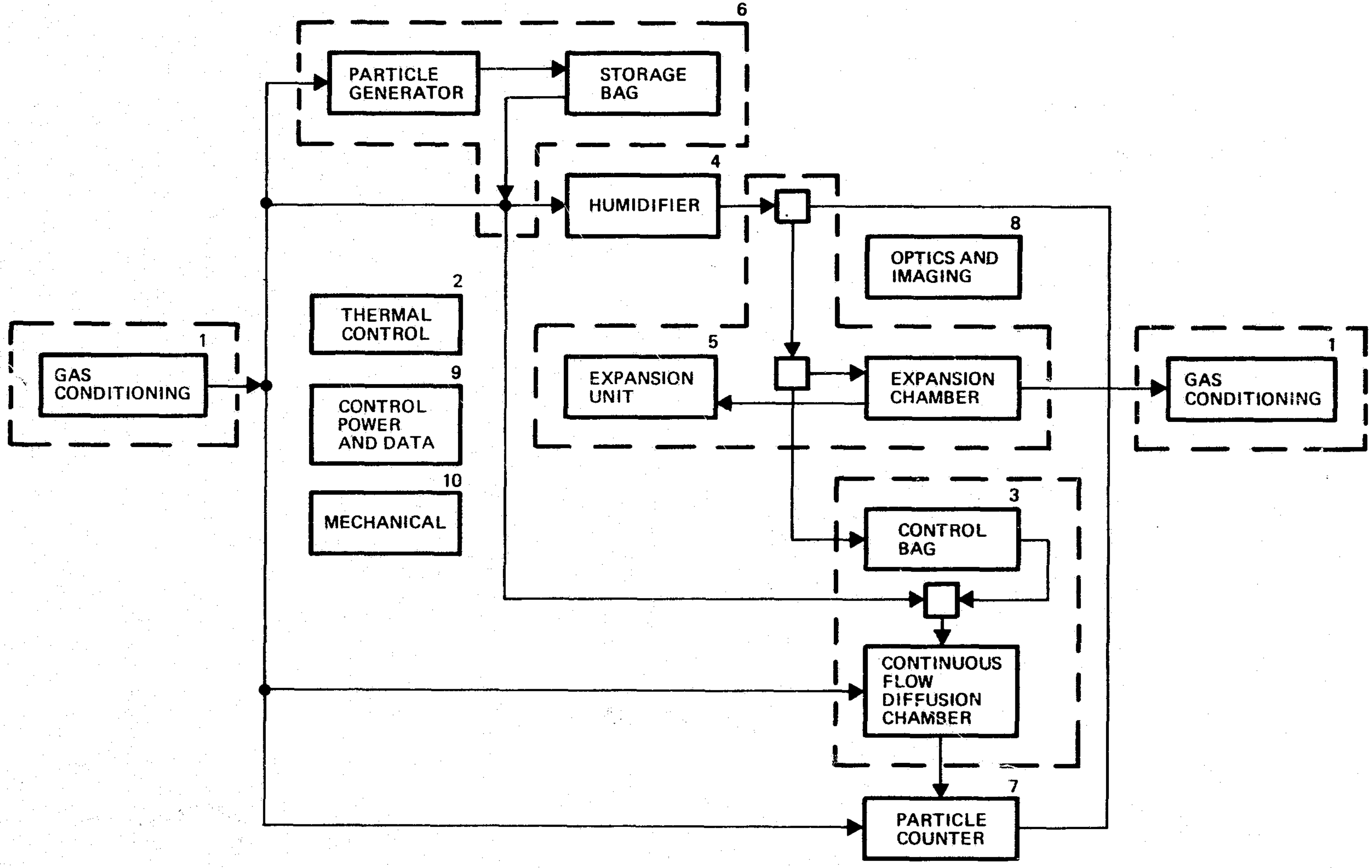
RALPH SCHILLING

SUBSYSTEM FUNCTIONS AND MAJOR COMPONENTS

NO.	SUBSYSTEM	FUNCTION	MAJOR ELEMENTS
1	FLUID CONTROL	FLUID SUPPLY, INLET GAS CONDITIONING, FLOW/PRESSURE REGULATION TO OTHER SUBSYSTEMS, EXHAUST/ RECIRCULATION	CO_2 ABSORBER DEHUMIDIFIER PARTICULATE FILTERS TRAP FOR HYDROCARBON MOLECULES BLOWERS FLOW RESTRICTORS FLOW AND PRESSURE SENSORS
2	THERMAL CONTROL	PROVIDES THERMAL INTERFACE BETWEEN OTHER ACPL SUBSYSTEMS AND SPACELAB THERMAL SINK	PUMP THERMAL CONTROL VALVE CHECK VALVES ACCUMULATORS THERMAL CAPACITOR TEM REFRIGERATOR
3	CONTINUOUS FLOW DIFFUSION CHAMBER	PROVIDES KNOWN SUPER-SATURATION TO ACTIVATE CONDENSATION NUCLEI AND GROW RESULTING DROPLETS TO OPTICALLY OBSERVABLE SIZE	DIFFUSION CHAMBER CONTROL BAG WATER SUPPLY THERMAL CONTROLLER PRESSURE AND TEMPERATURE SENSORS
4	HUMIDIFIER	PROVIDES SATURATED AIR AT PRECISELY KNOWN VALUES OF GAS STATE CONDITION	HUMIDIFICATION CHAMBER THERMAL CONTROLLER (REHEAT) WATER SUPPLY PRESSURE AND TEMPERATURE SENSORS
5	EXPANSION CHAMBER	SIMULATES ATMOSPHERIC ADIABATIC COOLING PROCESSES	CHAMBER WITH VARIABLE TEMPERATURE WALLS EXPANDER AND COMPRESSOR THERMAL CONTROLLER FLOW SELECTION VALVES PRESSURE AND TEMPERATURE SENSORS TE MODULES

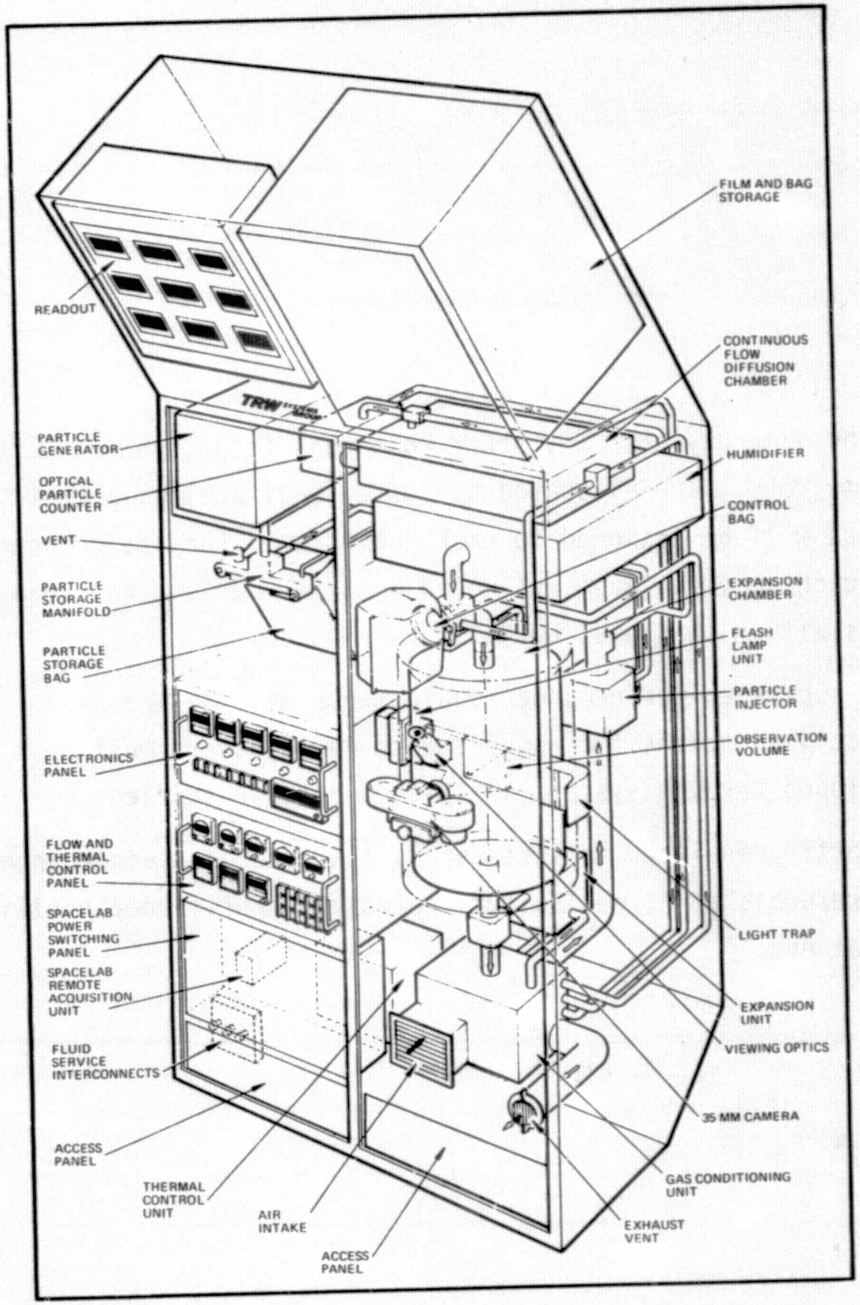
NO.	SUBSYSTEM	FUNCTION	MAJOR ELEMENTS
6	PARTICLE GENERATOR	PRODUCES, STORES AND DELIVERS PARTICLES OF VARIOUS TYPES, SIZES AND CONCENTRATION AS REQUIRED FOR EACH EXPERIMENT	PARTICLE GENERATOR(S) STORAGE BAGS FLOW SELECTION VALVES DILUTION MIXER
7	PARTICLE COUNTER	MEASURES NUMBER DENSITY AND SIZE DISTRIBUTION OF OPTICALLY OBSERVABLE CONDENSATION DROPLETS	OPTICAL BENCH ELECTRONIC SIGNAL PROCESSOR
8	OPTICS AND IMAGING	RECORDS NUMBER DENSITY OF OPTICALLY OBSERVABLE CONDENSATION DROPLETS WITHIN SPECIFIC VOLUME INSIDE EXPANSION CHAMBER	CAMERA WITH MOTORIZED FILM TRANSPORT FLASH LAMP OPTICS ASSEMBLY
9	CONTROL, POWER AND DATA	PROVIDES CONTROL OF TEMPERATURE AND PRESSURE THROUGHOUT THE SYSTEM, CONTROLS THE ADIABATIC SIMULATION CYCLE IN THE EXPANSION CHAMBER AND THE SUPERSATURATION RAMP IN THE CFD, PROVIDES PROPERLY CONDITIONED ELECTRICAL POWER AND COLLECTS DATA FROM ALL SENSORS	ELECTRONIC FEEDBACK CONTROL LOOPS SENSOR SIGNAL CONDITIONING CIRCUITRY POWER CONDITIONING CIRCUITRY SYSTEM CONTROLLER WITH EXPERIMENTER'S PANEL INTERFACE CIRCUITRY FOR SPACELAB REMOTE ACQUISITION UNIT
10	MECHANICAL	PROVIDES THE STRUCTURAL HARDWARE REQUIRED TO MOUNT THE ACPL COMPONENTS INTO SPACELAB RACKS	STRUCTURAL SUPPORTS

PRELIMINARY ACPL SYSTEM BLOCK DIAGRAM



TRW SYSTEMS GROUP

- ACPL components packaged in Spacelab double rack with expansion chamber internal to rack.
- CFD and humidifier horizontally oriented so wicking systems will function similarly under zero-g and one-g conditions.
- Electronics and particle generator packaged away from thermally sensitive elements.
- Room available to accommodate some system or subsystem growth.
- Most subsystems are separable elements which can be modified/replaced for evolutionary growth.



TRW SYSTEMS GROUP

- In the same way that any other resources (e.g., power, weight, volume, etc.) are allocated by system engineering, a cost target will be assigned to each subsystem. The design concepts for each subystem must evolve to meet the performance requirements within this cost budget.
- Some subsystem performance requirements will be provided directly as scientific requirements while others must be developed through systems analyses and trade studies.
- Supporting analyses include safety and hazards, maintenance and refurbishment, reliability, electromagnetic compatibility and others.

ACPL SYSTEMS ENGINEERING

- ANALYZE SCIENTIFIC REQUIREMENTS AND SPACELAB INTERFACES TO ESTABLISH SYSTEM REQUIREMENTS
- DEVELOP AND CONTROL SYSTEM CONFIGURATION AND RESOURCE BUDGETS
- DEFINE AND CONTROL SUBSYSTEM PERFORMANCE REQUIREMENTS
- DEFINE AND CONTROL SPACELAB AND INTERNAL INTERFACES
- PERFORM SYSTEMS AND INTERFACE ANALYSES AND TRADES
- PERFORM SUPPORTING ANALYSES
- DEFINE SOFTWARE REQUIREMENTS

We have selected the software trades and analyses as a specific example to further explain the systems engineering activities.

- The definition of software requirements will be closely coordinated with the control, power and data subsystem activities.
- One of the major system level trade studies will involve the partitioning of control and data handling functions between the Spacelab Command and Data Management Subsystem (CDMS) and the ACPL. The software architecture will be a primary consideration in this partitioning
- Maximum use will be made of ground based laboratory experience in determining the optimun approach to providing a liquid water content (LWC) correction for the adiabatic expansion.

SOFTWARE TRADES AND ANALYSES

- EVALUATE SPACELAB CDMS HARDWARE CAPABILITY
- TRADE OFF CDMS SOFTWARE VERSUS ACPL HARDWARE/SOFTWARE
- TRADE OFF REAL TIME VERSUS OFF-LINE LWC COMPUTATION
- DEVELOP SOFTWARE ARCHITECTURE
- PREPARE SOFTWARE SYSTEM FLOW DIAGRAMS
- PREPARE SPECIFICATIONS FOR MAIN PROGRAMS AND SUBROUTINES

TRW
SYSTEMS GROUP

MISSION OPERATIONS

PETE ROMO

A brief overview is presented for these two study topics. Each topic is explained in terms of its significance to the definition and design. Our proposed study approach is also described.

MISSION OPERATIONS

- GROUND SUPPORT EQUIPMENT (GSE) AND FLIGHT SUPPORT EQUIPMENT (FSE)

- GROUND AND FLIGHT OPERATIONS

TRW
SYSTEMS GROUP

The ACPL will require ancillary support equipment in addition to that provided by the Orbiter and Spacelab. For example, there may be a need for such support equipment as:

- a fill-and-drain system for the ACPL cooling loops, to be used in Level I integration;
- refrigeration system to supplement the Spacelab Experiment Heat Exchanger;
- high-voltage power supply for the ACPL flash lamps.

Every effort will be made to use GSE and FSE that will be available from STS, Spacelab, or from other programs so that ACPL program costs can be minimized. Where only ACPL-peculiar equipment can provide the required support, the necessary equipment will be functionally described.

GROUND AND FLIGHT SUPPORT EQUIPMENT DEFINITION

OBJECTIVE

A) TO DEFINE THE SUPPORT EQUIPMENT NEEDED BY ACPL

B) TO MINIMIZE ACPL PROGRAM COSTS THROUGH USE OF SPACELAB AND STS SUPPORT EQUIPMENT

APPROACH

1) STS AND SPACELAB GSE AND FSE LISTS WILL BE UPDATED AND INTERPRETED FOR ACPL DESIGN

2) REQUIREMENTS FOR GSE AND FSE WILL BE DEVELOPED

3) ACPL-PECULIAR GSE AND FSE WILL BE IDENTIFIED AND FUNCTIONAL DESCRIPTIONS WILL BE PREPARED

TRW
SYSTEMS GROUP

The STS and Spacelab will operate on precise schedules and will require that experiments conform to planned timelines, access constraints, environments and facilities. This study subtask will provide inputs on STS and Spacelab ground-processing procedures so that the evolving designs can be verified for compatibility.

As a special verification procedure, the full-scale mock-up of the ACPL will be used to insure compatibility. For example, the mock-up will help determine whether adequate access to ACPL components is available after racks are combined (Level III), after the combined racks are in the Spacelab (Level II), and after Spacelab is in the Orbiter (Level I).

GROUND OPERATIONS

OBJECTIVE

TO INSURE ACPL COMPATIBILITY WITH STS INTEGRATION TIMELINES, ACCESS CONSTRAINTS, ENVIRONMENTS AND FACILITIES

APPROACH

1) EARLY DEFINITION OF AN ACPL GROUND-PROCESSING SEQUENCE THAT FITS LEVEL III/II/I INTEGRATION SEQUENCES (SPACELAB AND ORBITER)
2) ITERATION OF DESIGNS AND GROUND-PROCESSING SEQUENCES TO DEVELOP OPTIMUM COMPROMISES
3) EXERCISE OF FULL-SCALE MOCK-UP TO VERIFY ACPL-STS COMPATIBILITY
4) GROUND-PROCESSING REQUIREMENTS FOR PEOPLE, ACCESS, GROUND EQUIPMENT, FACILITIES AND ENVIRONMENTS WILL BE DEFINED

TRW SYSTEMS GROUP

The ACPL must operate within the capabilities and constraints of the Orbiter, Spacelab, and associated operational-support systems. For example, some ACPL experiment may require an acceleration environment of 10^{-4}g (or better); for these instances, the experiment sequences (or parts of the sequences) must, therefore, be planned for periods when the Reaction Control System in inactive. The impacts of STS and Spacelab operations will be integrated into the study by developing experiment sequences and evaluating them for compatibility with STS and Spacelab operational capabilities.

The results of these analyses will also be useful for planning multidiscipline payloads; i.e., payloads that include ACPL as one group of experiments that will be assigned to a specific Spacelab flight.

FLIGHT OPERATIONS

OBJECTIVE

A) TO OPTIMIZE ACPL DESIGNS FOR ON-ORBIT OPERATIONS

B) TO DEVELOP PLANNING DATA (FOR STS OPERATORS) ON ACPL REQUIREMENTS FOR CONSUMABLES, ORIENTATION, CREW ACTIVITIES, DATA MANAGEMENT

APPROACH

1) CURRENT PAYLOAD ACCOMMODATIONS HANDBOOKS WILL BE REVIEWED AND INTERPRETED FOR ACPL DESIGN WORK

2) PRELIMINARY EXPERIMENT SEQUENCES AND CREW TIMELINES WILL BE DEVELOPED, BASED ON SCIENTIFIC REQUIREMENTS

3) EXPERIMENT SEQUENCES AND TIMELINES WILL BE COMPARED WITH THE SPACELAB/ STS CAPABILITIES FOR CONSUMABLES, ORIENTATION, CREW SUPPORT, DATA MANAGEMENT AND ENVIRONMENT. SEQUENCES OR DESIGNS WILL BE MODIFIED AS NECESSARY FOR COMPATIBILITY.

4) ON-ORBIT SCENARIOS WILL BE DEFINED, INCLUDING ACPL SUPPORT REQUIREMENTS ON STS, SPACELAB AND GROUND-CONTROL SYSTEM

TRW
SYSTEMS GROUP

SUBSYSTEMS ENGINEERING

BRUCE MARCUS

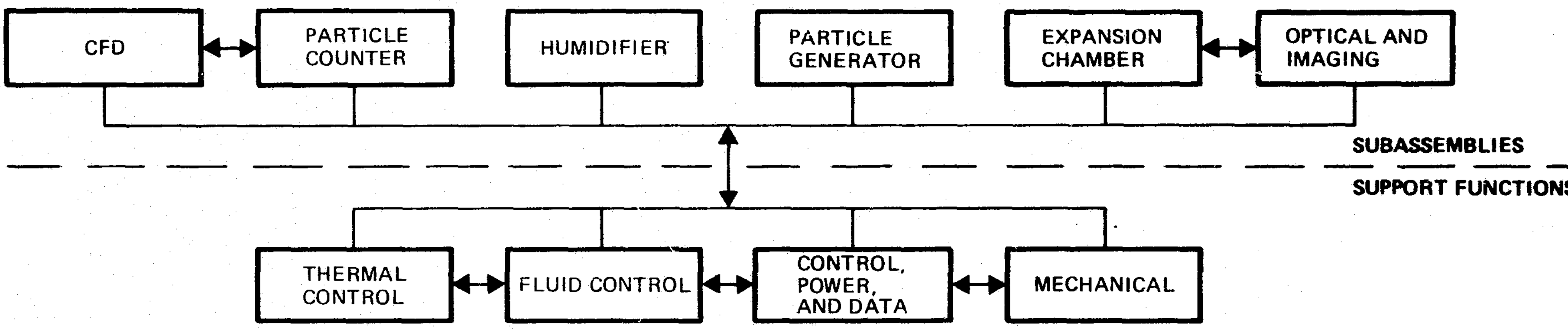
TRW
SYSTEMS GROUP

Ten ACPL subsystems have been identified which fall into two categories:

- subassemblies at the hardware level,
- support functions.

Interfaces have been defined such that subassemblies stand alone, including their unique thermal, fluid, etc. aspects. The supporting subsystems provide the link between the subassemblies and the Spacelab.

This presentation emphasizes the Fluid Control, Thermal Control, CFD, Humidifier, and Expansion Chamber subsystems. These either have major impact on the design of others or are thought to provide the greatest technical challenge.



ACPL SUBSYSTEMS AND INTERFACE RELATIONSHIP

TRW SYSTEMS GROUP

Methodology to be employed in subsystem analyses and trade studies.

Task Outputs:

- Preferred Concepts, Configurations, and Components
- Nominal Geometries
- Consumable Storage Requirements
- System and Subsystem Interface Parameters
- Operational Constraints
- FSE and GSE Requirements
- Cost Estimates
- Preliminary SR&T Requirements

SUBSYSTEM ANALYSES AND TRADE STUDIES

- ASSESSMENT OF GROUND-BASED LABORATORY FACILITIES FOR APPLICABILITY
- IDENTIFY CONCEPTUAL OPTIONS
- VENDOR SURVEY FOR APPLICABLE COMMERCIAL EQUIPMENT
- ANALYSES AND TRADE STUDIES
- INTERFACE COMPATIBILITY WITH OTHER SUBSYSTEMS
- RECTIFICATION OF RESOURCE REQUIREMENTS AND ALLOCATIONS

TRW SYSTEMS GROUP

Methodology to be employed in preliminary design.

Task Outputs:

- ACPL Preliminary Design
- Preliminary Design Document (SE-01)
- Interface Control Requirements
- Subsystem Specifications
- FSE and GSE Preliminary Designs
- Cost Estimates
- SR&T Requirements

PRELIMINARY DESIGN

- REFINE/MODIFY SUBSYSTEM ANALYSES TO ESTABLISH SPECIFIC ENGINEERING PARAMETERS
- GENERATE PRELIMINARY SCHEMATICS AND LAYOUTS
- COMPILE SUBSYSTEM COMPONENT LISTS. MAXIMIZE STANDARDIZATION AND UTILIZATION OF COMMERCIAL COMPONENTS
- DESIGN SUBSYSTEMS CONSISTENT WITH SUPPORTING ANALYSES (STRESS, DYNAMICS, EMI, FABRICATION ASSESSMENT, M&P).
- DESIGN ACPL ASSEMBLY
- CONDUCT SUBSYSTEMS PERFORMANCE AND SENSITIVITY ANALYSES
- DESIGN REQUIRED GSE AND FSE
- ESTIMATE COSTS FOR ACPL, GSE AND FSE

TRW
SYSTEMS GROUP

Fluid control subsystem task highlights

FLUID CONTROL SUBSYSTEM

FUNCTION: SUPPLIES AIR TO OTHER SUBSYSTEMS AT REQUIRED FLOW RATES AND STATE CONDITIONS

KEY DESIGN OBJECTIVE:

PROVIDE FLEXIBILITY FOR MULTIPLE EXPERIMENTS AND EVOLUTIONARY GROWTH AT MINIMUM PRACTICAL COST

GUIDELINES:

- SYSTEM PRESSURES (EXCEPT EXPANSION CHAMBER) ABOVE AMBIENT
- CO_2 CONTENT EQUIVALENT TO TERRESTRIAL CONDITIONS
- DEW POINT BELOW LOCAL WALL TEMPERATURES EXCEPT IN CFD, HUMIDIFIER AND EXPANSION CHAMBER
- CLEAN EXHAUST TO SPACELAB
- TOTAL FLOW ~ 1 LITER/SEC; STORAGE OF AEROSOL AND AEROSOL LADEN AIR
- CONTROL AEROSOL LOSSES

KEY TRADES:

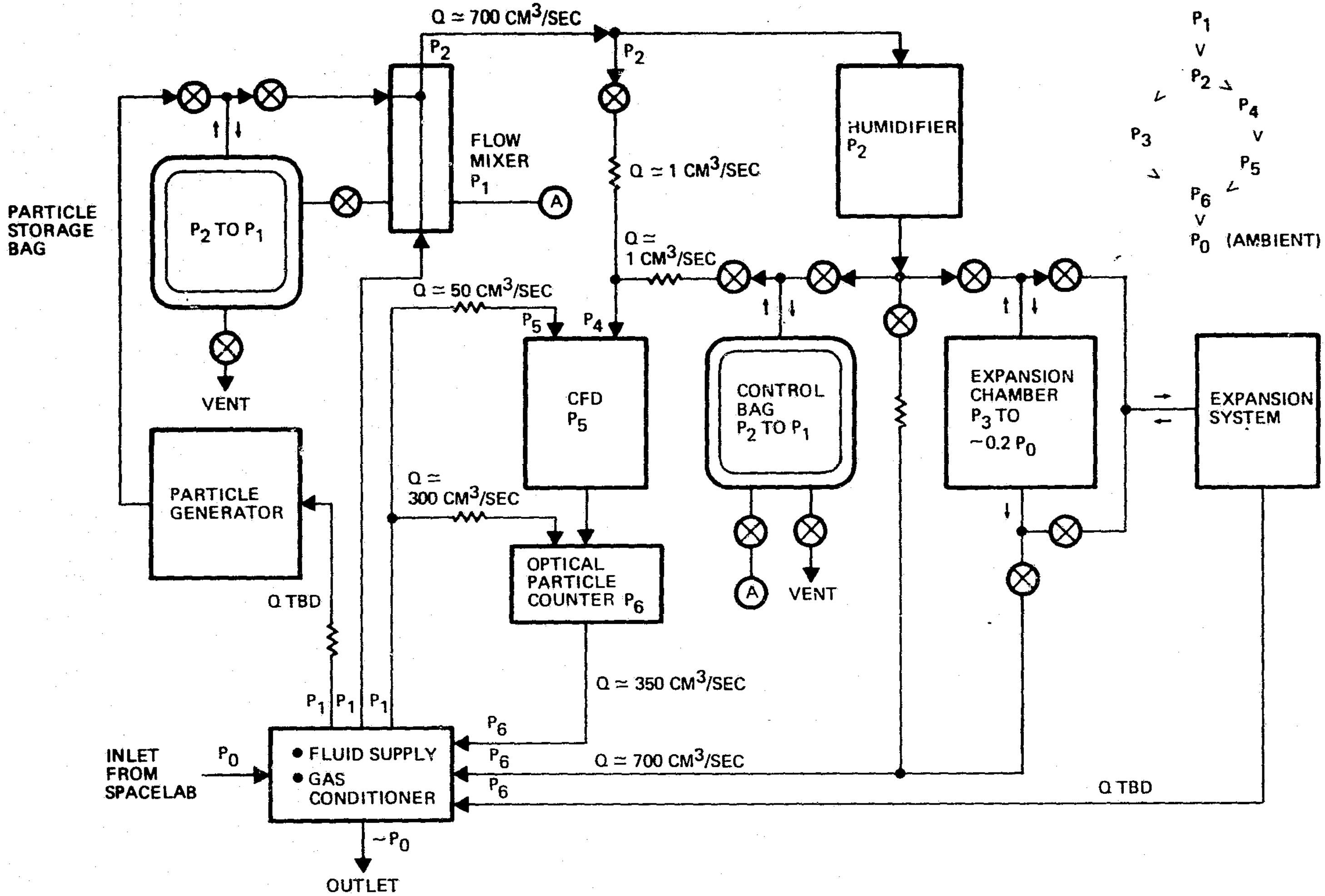
- OPEN CYCLE VS RECIRCULATION
- BALANCED LOOP VS INDIVIDUAL BRANCH CONTROL
- DOUBLE BAG VS ASPIRATED BAG

TRW
SYSTEMS GROUP

Representative fluid control subsystem flow schematic.

Features:

- Open cycle
- Flow restrictors provide balanced loop with common flow source
- Double bags make system independent of ambient pressure fluctations
- System operates above ambient pressure



ADVANTAGES

- MINIMIZES NUMBER OF COMPONENTS
- FLOW CONTROL SIMPLIFIED
- SIMPLIFIES SYSTEM FLUSHING FOR PARTICLE TYPE CHANGES

DISADVANTAGES

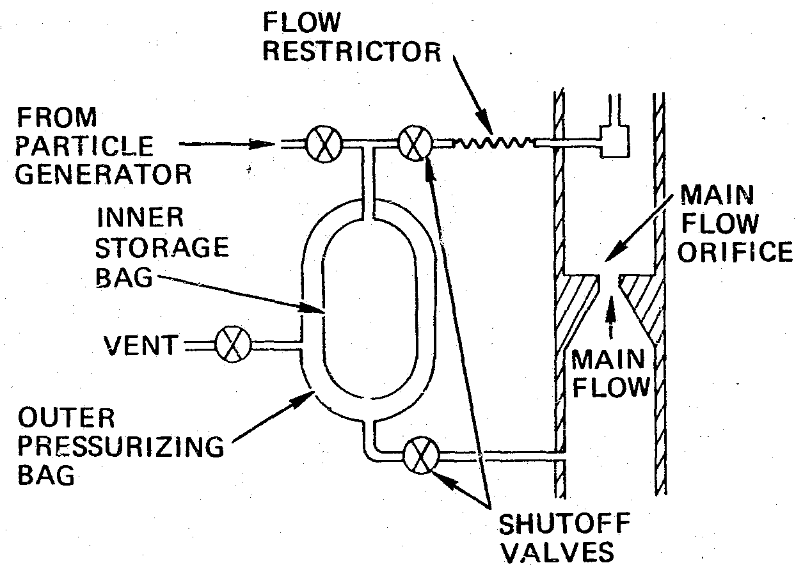
- MAXIMIZES GAS CONDITIONING REQUIREMENTS
- MAXIMIZES HUMIDIFIER WATER STORAGE

TRW SYSTEMS GROUP

REPRESENTATIVE FLUID FLOW SCHEMATIC

Double bag storage and flow mixer concept provides a constant sample flow rate independent of ambient pressure variations. Outer bag provides stable pressure environment for inner bag containing the sample. Orifice in constant main flow stream provides a fixed pressure differential. Flow restrictor in sample flow stream provides a specified sample flow rate.

PRELIMINARY DESIGN CONCEPT: AEROSOL FLOW MIXER



DOUBLE BAG FOR AEROSOL STORAGE COUPLED WITH USE OF MAIN FLOW STREAM FOR PRESSURE CONTROL PROVIDES INEXPENSIVE APPROACH TO ACHIEVE CONSTANT SAMPLE FLOW RATE INDEPENDENT OF AMBIENT PRESSURE VARIATIONS

TRW SYSTEMS GROUP

Thermal control system task highlights.

THERMAL CONTROL SUBSYSTEM

FUNCTION: THERMAL INTERFACE BETWEEN OTHER ACPL SUBSYSTEMS AND ULTIMATE HEAT SINK (SPACELAB OR SPACE VACUUM)

KEY TRADES:

- o SOURCE OF REFRIGERATION: TEM'S VS SUBLIMATOR
- o DIVISION OF REFRIGERATION AND/OR TEMPERATURE CONTROL FUNCTIONS BETWEEN TCS AND INDIVIDUAL SUBSYSTEMS

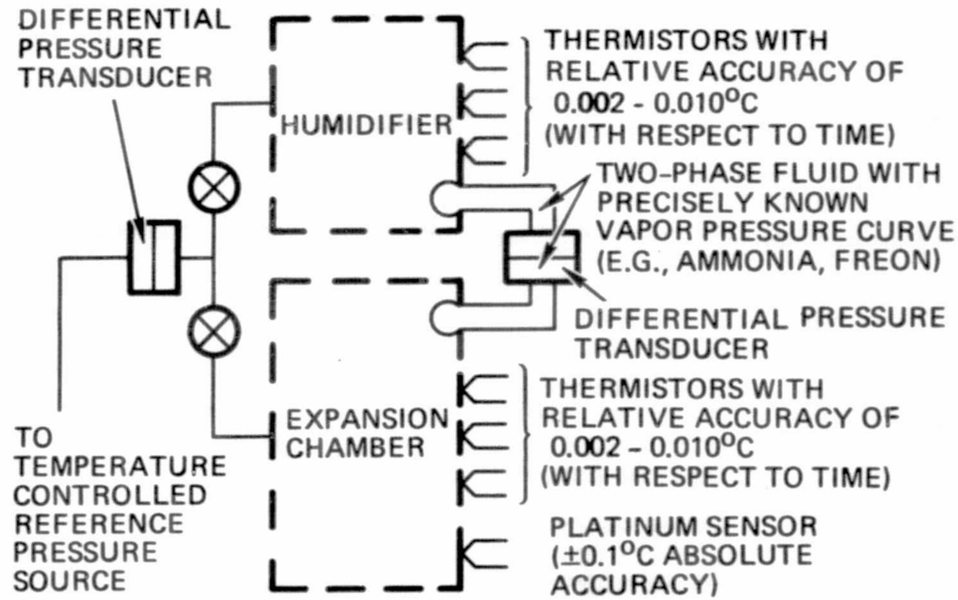
KEY TEMPERATURE MEASUREMENT PROBLEM:

ΔT BETWEEN EXPANSION CHAMBER AND HUMIDIFIER, DISPLACED IN TIME

TRW
SYSTEMS GROUP

Measurement of vapor pressure differential of two-phase fluid reservoirs in humidifier and expansion chamber allows very precise determination of temperature differences. Use of single differential pressure transducer (referenced to temperature-controlled reference pressure source) allows very precise pressure difference measurement.

PRELIMINARY DESIGN CONCEPT: TO RELATE HUMIDIFIER AND EXPANSION CHAMBER PRESSURE AND TEMPERATURE



TRW SYSTEMS GROUP

Continuous-flow diffusion chamber subsystem task highlights.

CONTINUOUS FLOW DIFFUSION CHAMBER SUBSYSTEM

FUNCTION:

- PROVIDES KNOWN SUPERSATURATION TO ACTIVATE CONDENSATION NUCLEI AND GROW RESULTING DROPLETS TO OPTICALLY OBSERVABLE SIZE
- USED TO MEASURE AEROSOL DISTRIBUTION IN CRITICAL SUPERSATURATION
- o ALSO PROVIDES CAPABILITY FOR DROPLET GROWTH STUDIES

DESIGN OBJECTIVES:

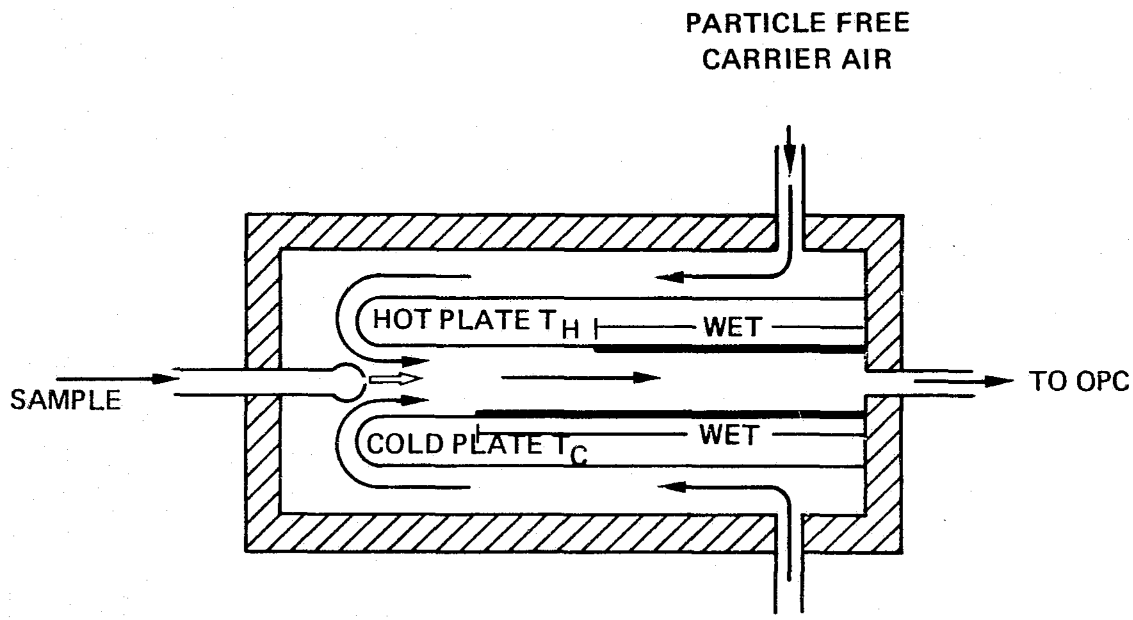
- MAKE MAXIMUM USE OF GROUND-BASED TECHNOLOGY
- MODIFY AS NEEDED TO ACCOMMODATE ACPL ENVIRONMENTS (LAUNCH, ZERO-G)

MAJOR ANALYSES AND TRADES:

- CAPILLARY PUMPED WATER DISTRIBUTION SYSTEM
- NUMERICAL MODELING OF MASS DENSITY, HUMIDITY FIELD, AND DROPLET BEHAVIOR PROVIDES DATA TO DESIGN WICKS AND COMPARE 1-G VS 0-G PERFORMANCE
- THERMAL CONTROL TECHNIQUES

TRW SYSTEMS GROUP

A typical continuous-flow diffusion chamber consists of two temperature-controlled parallel plates, with portions of their facing surfaces maintained wet. Temperature conditioned carrier air draws an aerosol sample through a supersaturated region between the plates where droplets grow to a size observable in the OPC. The supersaturation level is a direct function of the two plate temperatures.



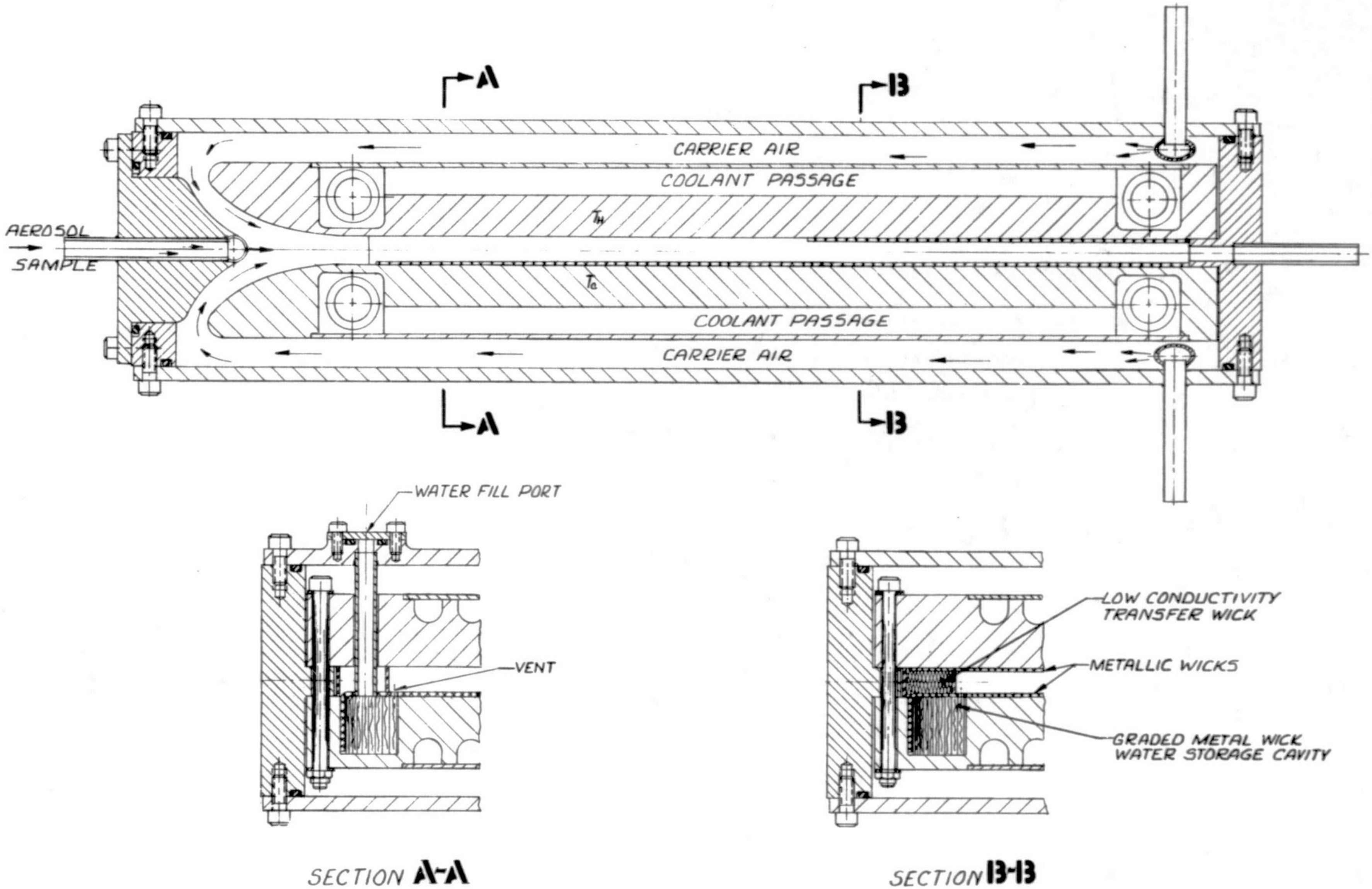
Schematic Diagram of a CFD Chamber

TRW
SYSTEMS GROUP

Preliminary layout of an ACPL continuous-flow diffusion chamber.

Features:

- Similar to ground-based facilities.
- Wicking system for control of water in both zero-g and one-g.
- Pumped-coolant temperature control. Coolant in counterflow to air stream provides maximum temperature control in most critical downstream region.
- Shaped reversal of carrier air flow path minimizes spreading of sample.

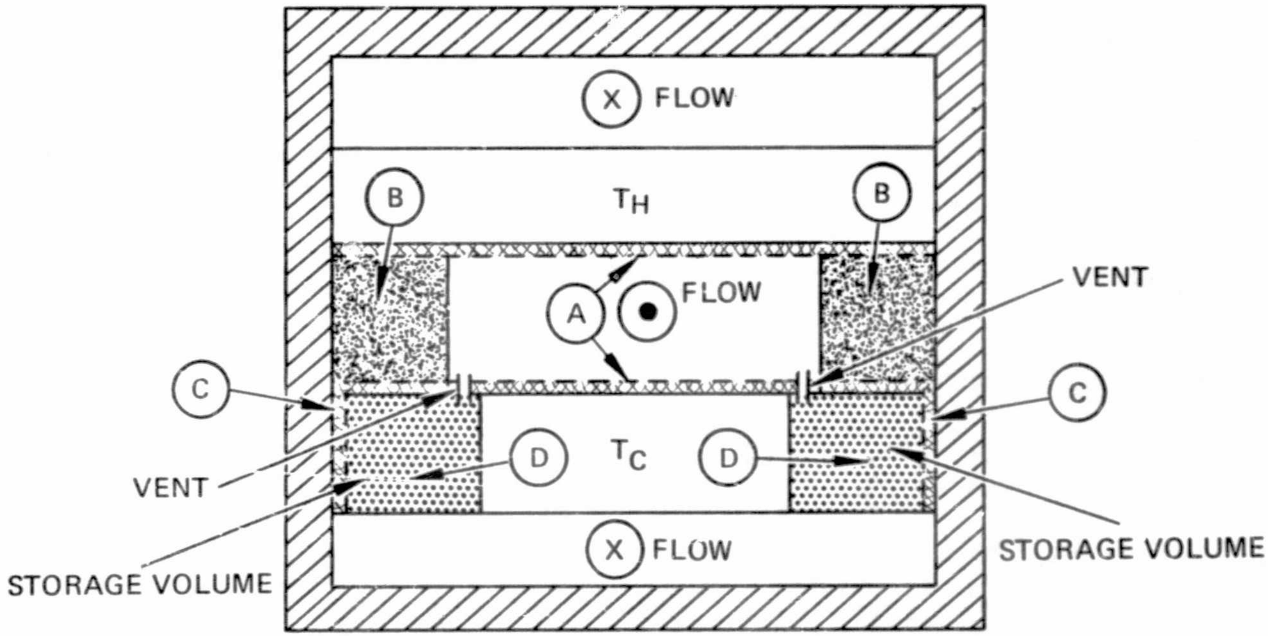


CONTINUOUS FLOW DIFFUSION CHAMBER

TRW
SYSTEMS GROUP

CFD wick system features:

- High-conductivity plate wicks provide for minimum wick temperature drops, improving the accuracy with which the supersaturation field is known.
- Low-conductivity, isolated transfer wicks have minimum impact on the temperature and humidity fields.
- Water storage for continuous operation over seven-day flight, and control of water location within reservoirs to assure venting.
- Insensitive to air pressure level.
- Operates in both zero-g and one-g (horizontal).



(A) SINTERED HIGH CONDUCTIVITY "WET WALL" WICKS DIFFUSION-BONDED TO PLATES. COLD PLATE WICK EXTENDS INTO WATER STORAGE RESERVOIRS.

(B) LOW CONDUCTIVITY FIBER WICKS TO TRANSFER WATER BETWEEN PLATES – ISOLATED FROM AIR FLOW.

(C) EXTENSIONS OF COLD PLATE WICK TO TRANSFER WATER FROM STORAGE VOLUMES.

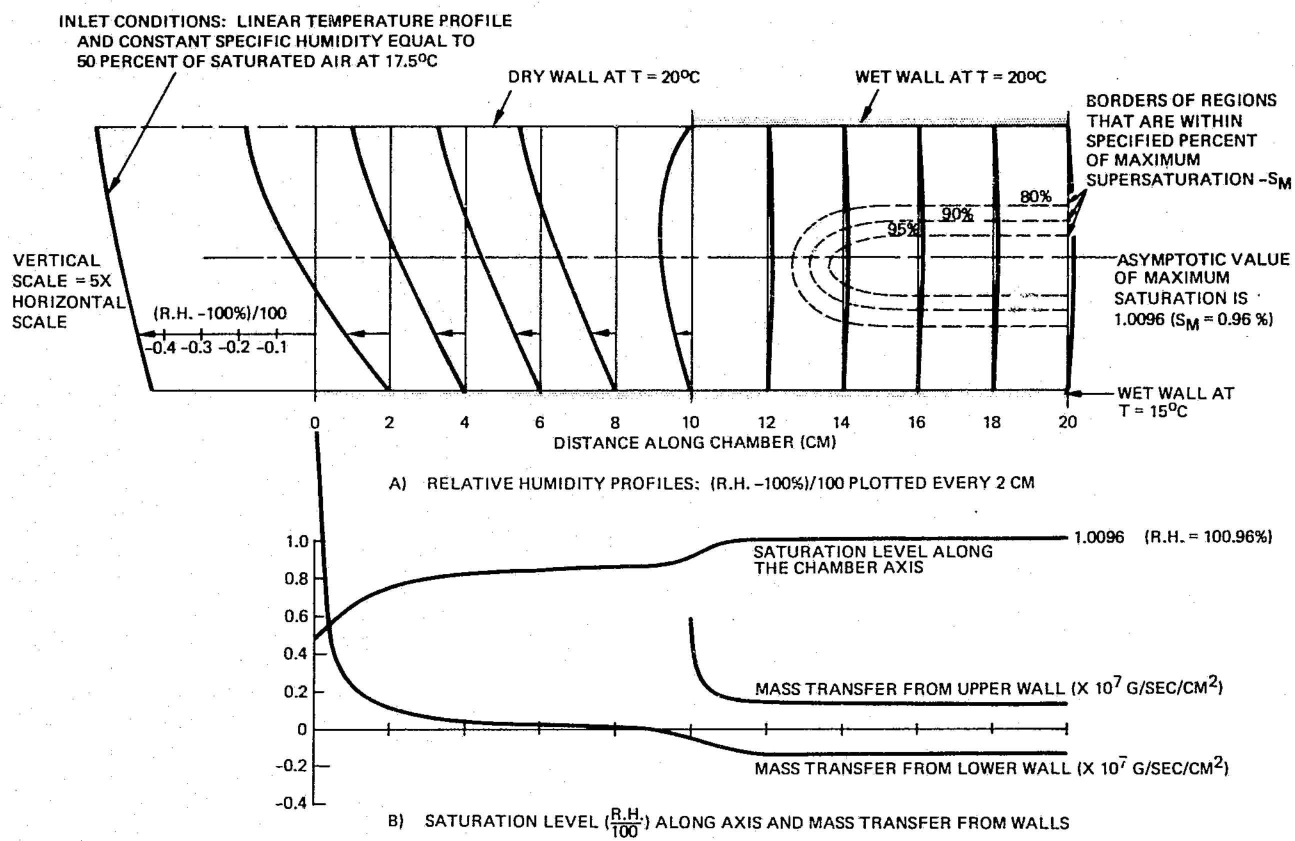
(D) GRADED POROSITY WICKS TO CONTROL FLUID LOCATION IN STORAGE VOLUMES.

Candidate Wick System for the CFD

TRW
SYSTEMS GROUP

Modified RHOGS computer program permits numerical modeling of mass density, mass flux, and humidity fields between plates. Such data is needed to:

- design the wick system and calculate wick temperature drops,
- perform droplet trajectory calculations,
- compare predicted zero-g and one-g performance. Similarity is necessary to establish a preflight data base for evaluating flight results.



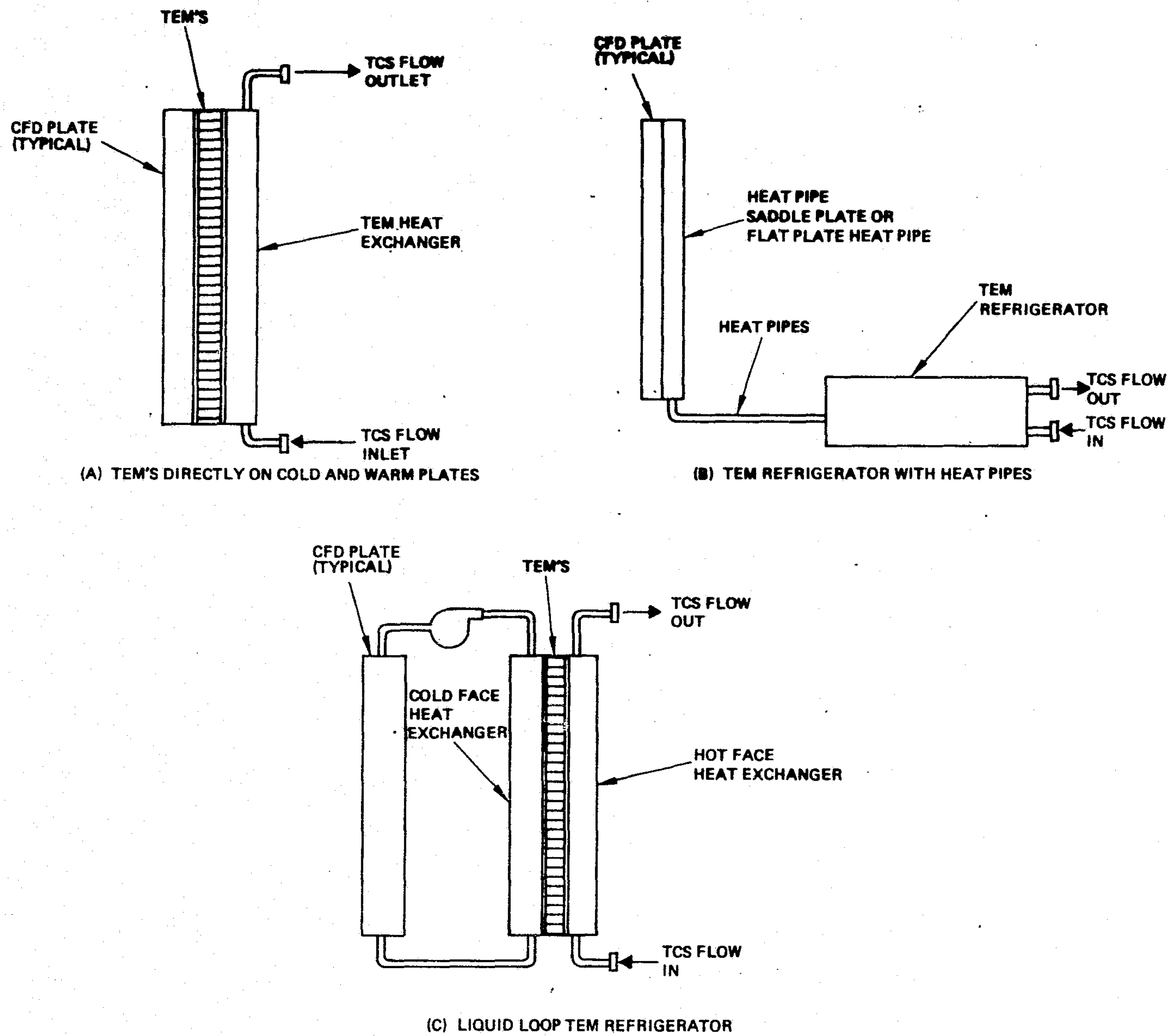
Typical Results of CFD Numerical Analysis Obtained with Modified RHOGS Computer Program

TRW
SYSTEMS GROUP

CFD thermal control techniques where thermoelectric modules provide refrigeration at the CFD subsystem. System C - liquid loop TEM refrigerator would be consistent with preliminary CFD layout.

CFD plate temperature uniformity can be provided with:

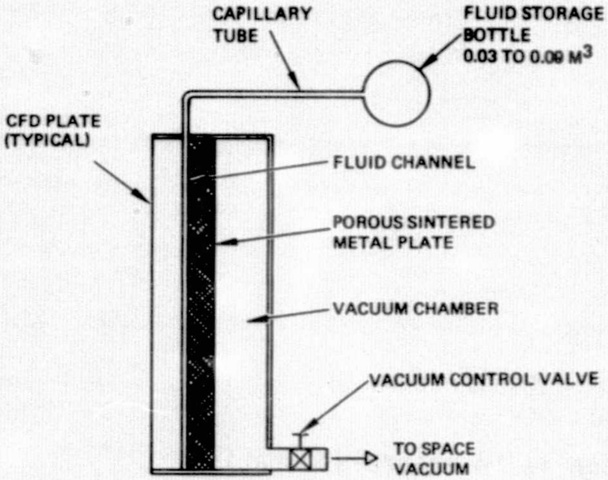
- massive high-conductivity plates;
- large, high-flow-rate, circulating fluid baths;
- flat (vapor chamber) heat pipes.



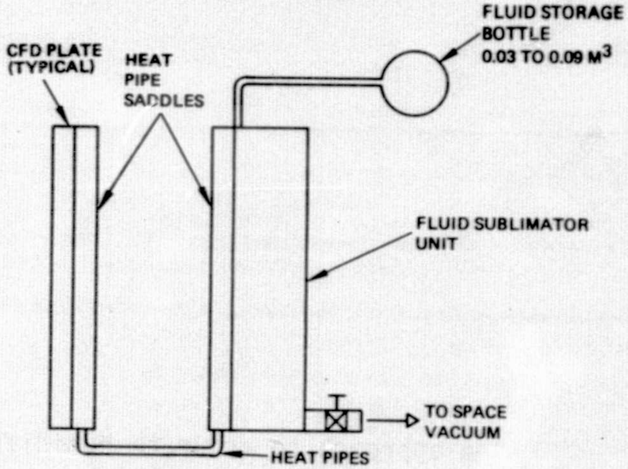
CFD THERMOELECTRIC REFRIGERATOR

TRW
SYSTEMS GROUP

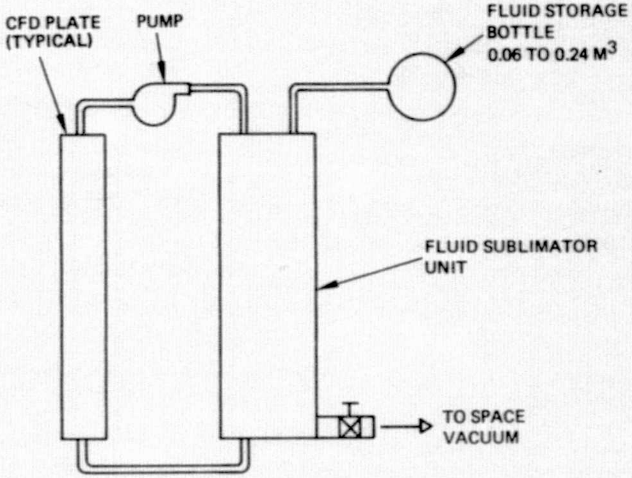
CFD thermal control techniques where fluid sublimator provides refrigeration at the CFD subsystem.



(A) DIRECT ACTING FLUID SUBLIMATOR



(B) FLUID SUBLIMATOR WITH HEAT PIPES



(C) LIQUID LOOP FLUID SUBLIMATOR

CFD FLUID SUBLIMATOR

The approach to accurate humidification is to ensure saturation of the air at a known temperature and pressure with greater certainty than that with which humidity can be measured in situ.

HUMIDIFIER SUBSYSTEM

FUNCTION:	TO PROVIDE AIR TO THE EXPANSION CHAMBER WITH PRECISELY KNOWN AND CONTROLLED SPECIFIC HUMIDITY
KEY PROBLEM:	REQUIRED ACCURACY (0.01 - 0.05%) BEYOND STATE-OF-THE-ART FOR HUMIDITY MEASUREMENTS
APPROACH:	SATURATE AIR IN FLOW OVER TEMPERATURE-CONTROLLED, WETTED WALLS, AND THEN REHEAT IT OVER DRY WALLS TO LOWER THE RELATIVE HUMIDITY AND PREVENT SUBSEQUENT CONDENSATION

TRW SYSTEMS GROUP

Flow geometry must lend itself to accurate analysis.

Water distribution system must maintain surfaces wet but prevent entrainment.

Temperature of water-air interfaces must be precisely known and controlled, particularly toward the downstream end of the humidification region.

Humidifier-Reheater interface design must assure a) no condensation of the saturated air, and b) no significant influence of the reheater on the temperature and humidity levels at the end of the humidification region.

Temperature control considerations are similar to those for the CFD.

An accurate technique for measuring humidity, at least in a ground-based engineering test, would lend confidence to the humidifier design.

Major Analyses and Trade Studies

ANALYSIS OR TRADE STUDY	PRINCIPAL RESULTS
DETAILED THERMAL MODELING OF CHAMBER GEOMETRY	PREFERRED ASPECT RATIO AND LOCATIONS FOR WINDOWS AND FLOW PORTS SO AS TO MINIMIZE WALL EFFECTS ON OBSERVATION ZONE, CONSISTENT WITH OPTICAL AND FLOW REQUIREMENTS
TRADE STUDIES BETWEEN CANDIDATE EXPANSION SYSTEMS	PREFERRED SYSTEMS IN TERMS OF COMPLEXITY, OPERATIONAL FLEXIBILITY, WEIGHT, POWER, VOLUME, AND COST AS A FUNCTION OF CAPABILITY REQUIREMENTS
FLOW SYSTEM TRADE STUDIES: FLOW FIELD GEOMETRY, INLET AND OUTLET PORTS, PLENUMS OR MANIFOLDS	PREFERRED SYSTEM WITH RESPECT TO: • MINIMIZING OBSERVATION ZONE DISTURBANCES • PROVIDING THOROUGH CHAMBER FLUSHING • MINIMIZING PARTICLE LOSSES • EASE OF CLEANING
TEMPERATURE CONTROL TRADE STUDIES: CHAMBER THERMAL CONTROL - TEMS VERSUS FLUID SUBLIMATOR FOR REFRIGERATOR	PREFERRED SUBSYSTEM REFRIGERATOR APPROACH IN TERMS OF ACPL AND SPACELAB INTERFACE REQUIREMENTS, PERFORMANCE, POTENTIAL FOR GROWTH, AND COST
WINDOW THERMAL CONTROL; SAPPHIRE VERSUS LIQUID COOLED VERSUS VAPOR CHAMBER WINDOWS	PREFERRED APPROACH BASED ON PERFORMANCE, COMPLEXITY, AND COST

TRW
SYSTEMS GROUP

Preliminary layout of an ACPL humidifier.

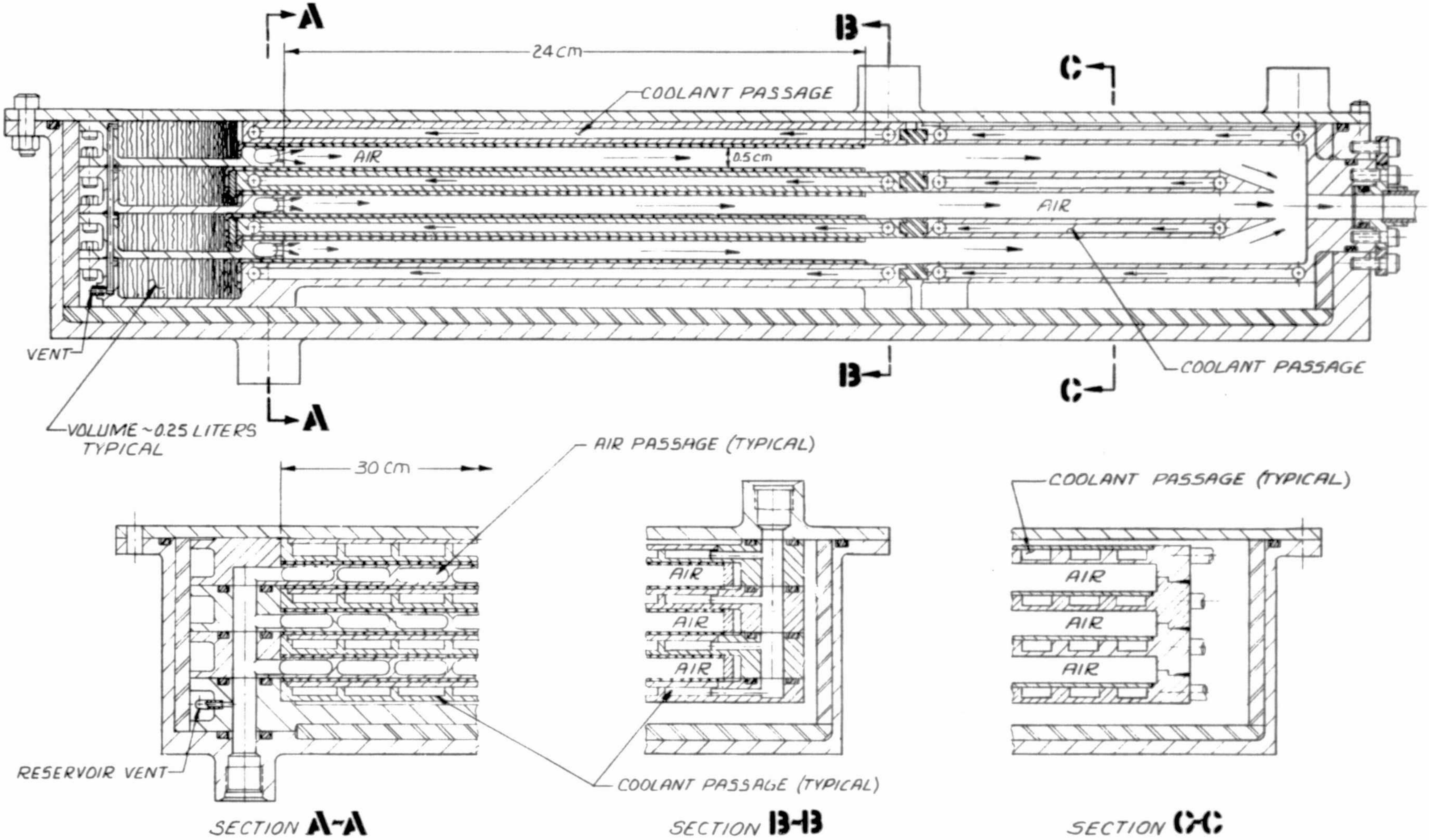
Features:

- 750 cm^3/sec flow through three high-aspect ratio (30 cm x 0.5 cm) ducts with 24-cm wetted-length yields > 99.99% RH.

- Capillary-pumped water distribution system. Channel wall wicks draw water from self-contained storage reservoirs sized for seven days continuous operation (80% humidifier flow recirculation). Reservoirs contain graded porosity wicks to control water location and are vented to air stream for pressure equalization.

- Sintered copper wicks on channel walls minimize wick temperature drops. Co-current wick water-air flow and counter-current coolant-air flow provide maximum temperature control at critical downstream end of humidification region.

- Thermal isolation and temperature controlled dry surface zone minimize reheater effects on humidification region. Common humidifier-reheater package avoids condensation.



HUMIDIFIER

TRW SYSTEMS GROUP

The expansion chamber subsystem is the heart of the ACPL when used for most cloud physics experiments. Within the chamber, humidified air, laden with cloud condensation nuclei (CCN), is adiabatically expanded to simulate an atmospheric updraft. The resulting supersaturated condition leads to condensation on the CCN and formation of a cloud of droplets. This process is photographed as primary experimental data.

EXPANSION CHAMBER SUBSYSTEM

FUNCTION: SIMULATES ATMOSPHERIC ADIABATIC COOLING PROCESSES LEADING TO CLOUD FORMATION

KEY REQUIREMENTS:

- WALL TEMPERATURES MUST BE CONTROLLED TO MINIMIZE EFFECTS ON ADIABATIC EXPANSION
- EXPANSION SYSTEM TO REDUCE PRESSURE CORRESPONDING TO WALL TEMPERATURE PROFILE
- INLET AND OUTLET FLOW SYSTEM TO FILL AND PURGE CHAMBER
- OPTICAL WINDOWS FOR ILLUMINATING AND PHOTO-GRAPHING CLOUD FORMATION PROCESS

NEW TECHNICAL PROBLEM:

MINIMIZING WALL EFFECTS ON OBSERVATION ZONE

APPROACH: DESIGN ON TRANSIENT BASIS, MAXIMIZING TIME PERIOD FOR WALL TEMPERATURE EFFECTS TO ALTER CONDITIONS IN OBSERVATION ZONE

TRW SYSTEMS GROUP

Chamber geometry should be designed to minimize wall effects on the observation zone.

Expansion system must provide for deep expansions as well as removal and reinsertion of a limited volume of air, one or more times, without introducing new air (memory experiments).

The inlet and outlet flow system must be designed to (1) minimize particle diffusion losses, (2) provide thorough, laminar flow flushing during fill, (3) minimize observation zone disturbances during expansion, and (4) facilitate cleaning.

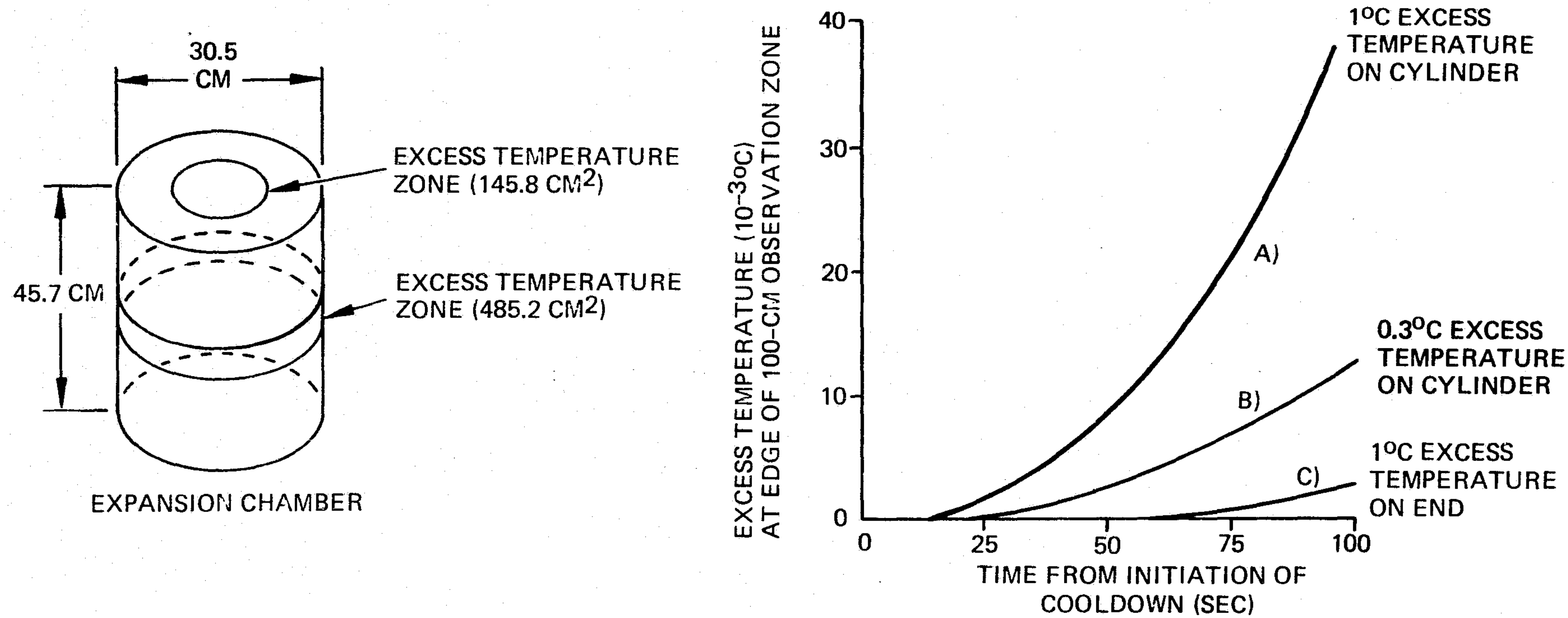
Temperature control considerations are similar to those for the CFD, with thermoelectric and liquid sublimator refrigeration options. However, uniformity requirements during cooling transient make task more difficult. Windows and other thermal mass discontinuities in the structure require special attention.

ITEM	PRINCIPAL RESULTS
• **FLOW GEOMETRY TRADE** STUDY. FLOW THROUGH TUBES VERSUS RECTANGULAR DUCTS	PREFERRED FLOW GEOMETRY BASED ON RELATIVE: • NUMBER OF FLOW CHANNELS • WETTED AREA REQUIRE MENTS • REYNOLDS NUMBERS • PRESSURE DROPS
• **WATER DISTRIBUTION SYSTEM TRADE STUDIES.** PRESSURE FEED VERSUS CAPILLARY PUMPING. HUMIDIFICATION WITH THERMAL CONTROL FLUID OR SEPARATE STORED SUPPLY	PREFERRED WATER DISTRIBU TION SYSTEM BASED ON RELATIVE: • OPERATIONAL RELIABILITY • SENSITIVITY TO CONTAMI NATION • COMPLEXITY OF CONTROL SYSTEMS • EASE OF REFURBISHMENT • POTENTIAL FOR ICE EXPERIMENTS
• ANALYSIS OF TEMPERATURE DROPS FROM CONTROLLED SURFACE (OR FLUID) TO LIQUID-AIR INTERFACE	TEMPERATURE DISTRIBUTION ALONG LIQUID–AIR INTERFACE IN RELATION TO THAT OF CONTROLLED SURFACE (OR FLUID)
• **HUMIDIFIER-REHEATER INTERFACE TRADE STUDIES.** SEPARATE VERSUS INTEGRATED DESIGN. THERMAL ISOLATION VERSUS SURFACE LAYER SUCTION VERSUS PRESCRIBED REHEATER TEMPERATURE PROFILE	PREFERRED METHOD OF PROVIDING REHEAT WITHOUT ALTERING SPECIFIC HUMIDITY OF AIR
• **TEMPERATURE CONTROL SYSTEM.** TCS SUPPLIED COOLANT VERSUS INDEPENDENT LOOP FLAT PLATE HEAT PIPES VERSUS FLUID HX PLATES THERMAL MASS IN PLATES OR FLUID REFRIGERATION METHOD TRADEOFF	TCS INTERFACE REQUIRE-MENTS POWER REQUIREMENTS VACUUM SOURCE INTER-FACE REQUIREMENTS TEMPERATURE STABILITY VERSUS CONTROL METHOD
• SEARCH FOR AND EVALUATION OF POTENTIAL HUMIDITY MEASUREMENT TECHNIQUES	IDENTIFICATION OF CANDIDATE TECHNIQUES FOR SR&T DEVELOPMENT

MAJOR ANALYSES AND TRADE STUDIES

TRW SYSTEMS GROUP

Results of thermal modeling studies show that observation zone response to wall temperature nonuniformities depends on location of deviation. More sensitive to deviations on the cylinder than on the ends. This suggests short, large-diameter chamber. However, must also consider optics and flow system in design.



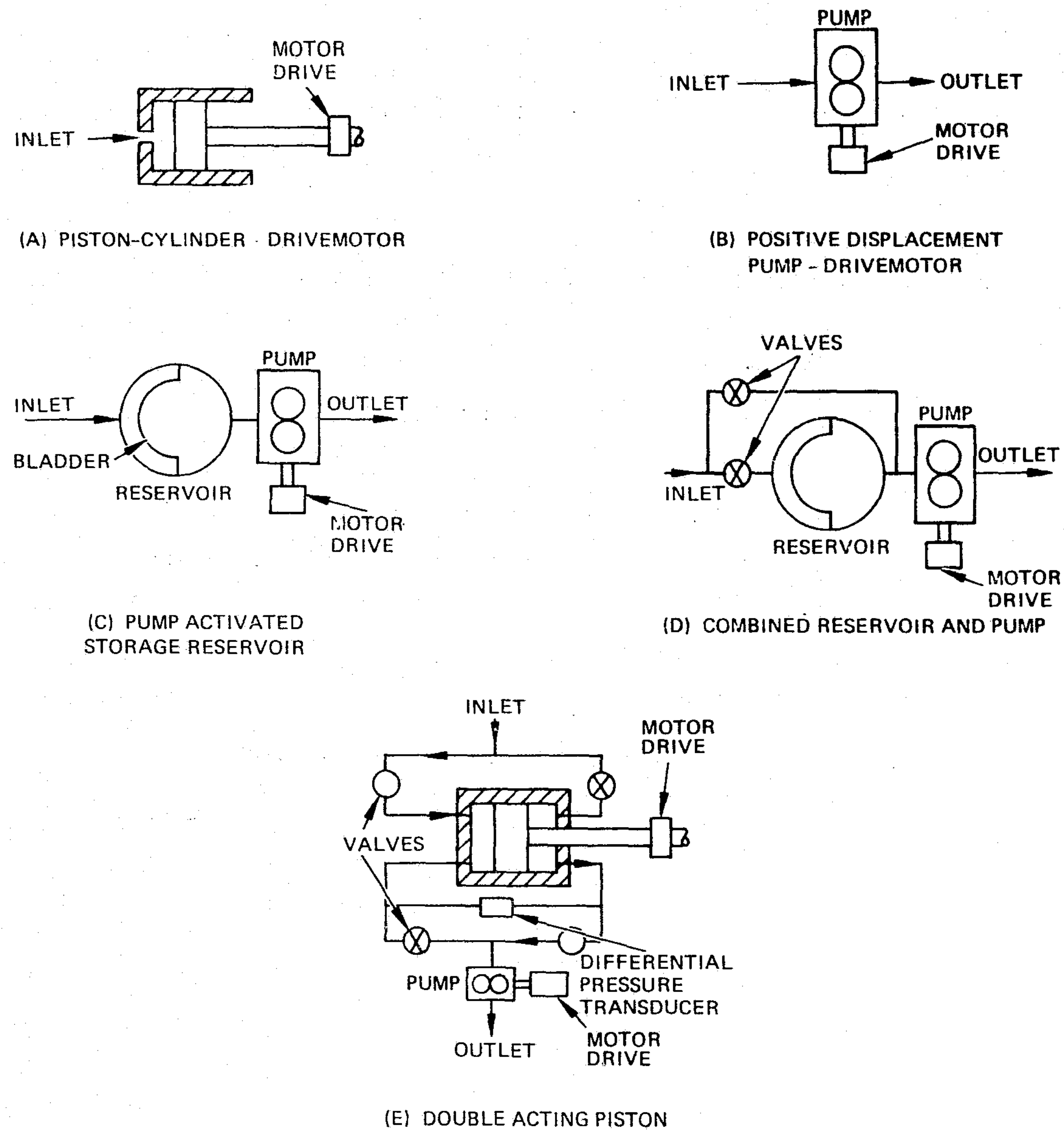
Expansion Chamber Gas Temperature Response to Localized Wall Temperature

TRW
SYSTEMS GROUP

Concepts (A) and (C) provide for small expansions and reinjection, but are not suitable for deep expansions.

Concept (B) permits deep expansions but has no reinjection capability.

Concepts (D) and (E) provide for both deep expansions and reinjection.

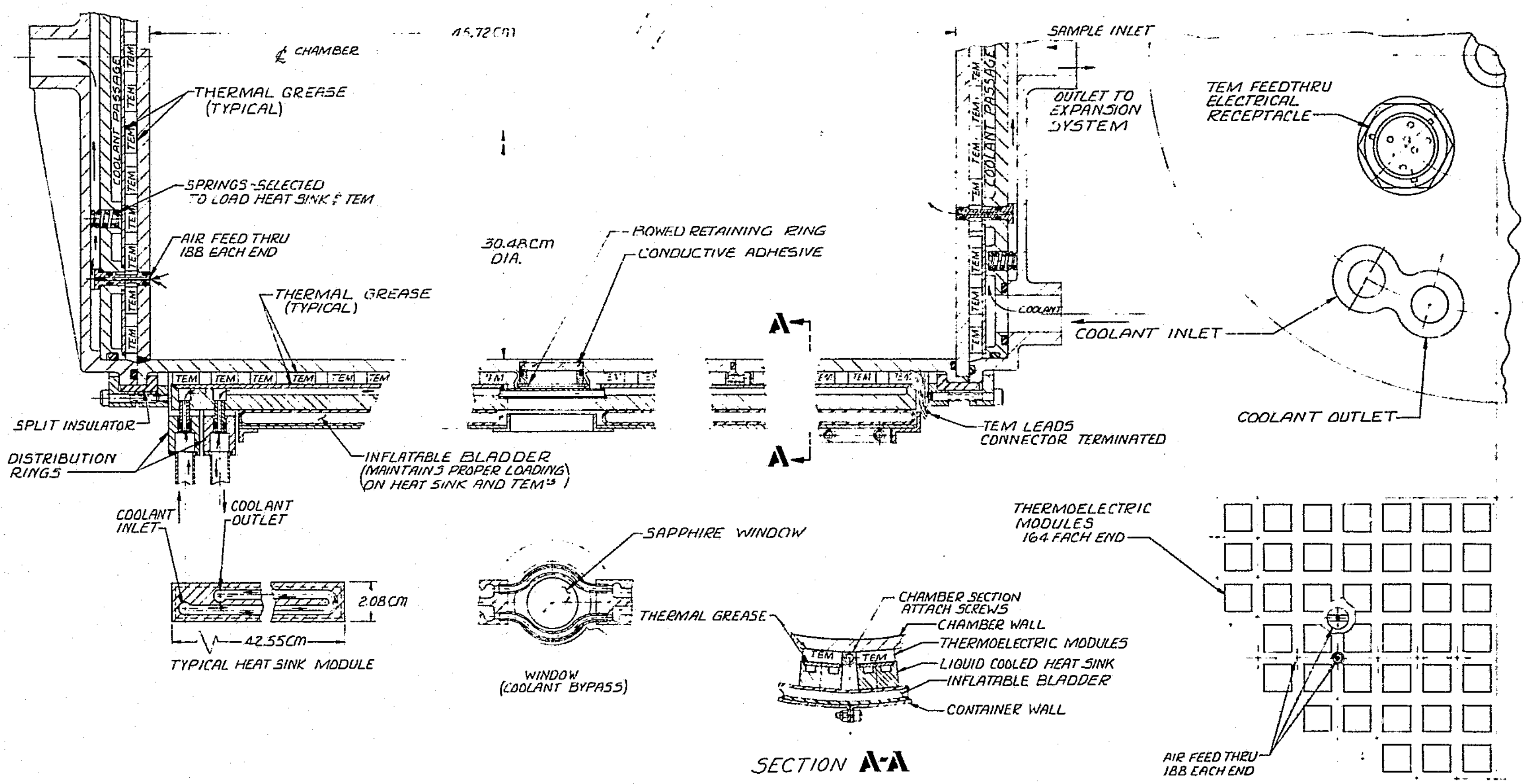


EXPANSION SYSTEM DESIGN CONCEPTS

Preliminary layout of an ACPL expansion chamber.

Features:

- Cylindrical geometry with multiple removable flow ports at both ends results in laminar "piston" flow during purge, fill and expansion operation. Inner cylindrical wall made of multiple sections with O-ring seals, allowing modification of length. Design permits disassembly for cleaning.
- Liquid-cooled TEM's provide temperature control. Springs and pressurized circumferential bladder yield uniform loading for improved heat transfer and protection of fragile TEM's. Two-pass heat exchangers improve temperature uniformity.
- Sapphire inner windows aid in thermal control.
- Maximum use of standard parts, materials, and processes.



EXPANSION CHAMBER

TRW
SYSTEMS GROUP

STUDY PLAN OVERVIEW

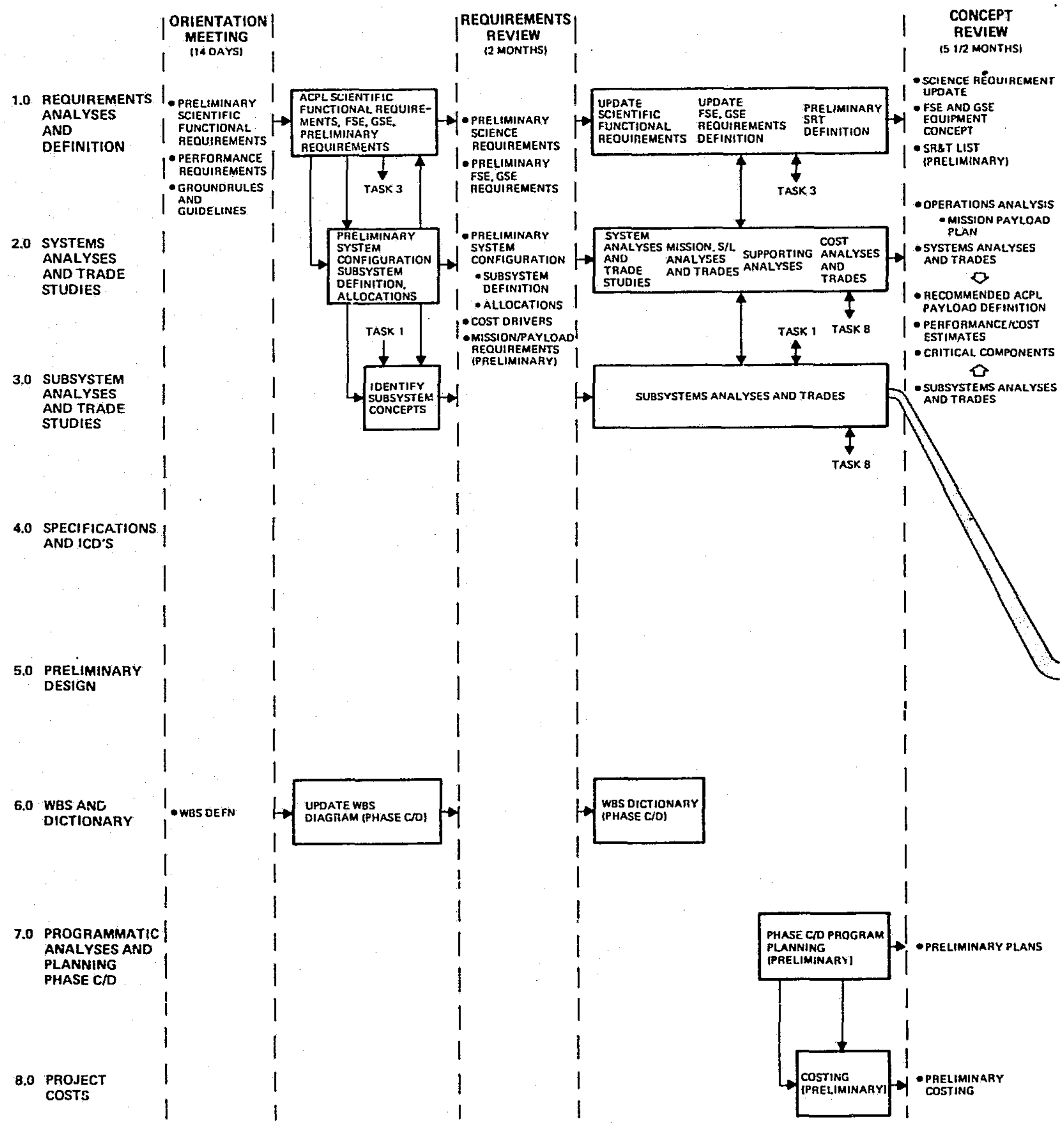
BILL CLAUSEN

The ACPL Phase B Preliminary Design Study has been divided into eight major tasks as shown on the facing page, and further subdivided into 30 subtasks. Task 1 deals with analysis and definition of requirements, Tasks 2, 3 and 4 with design activities, and Task 5 with documentation of that design. Tasks 6, 7 and 8 are directed at planning and costing of the Phase C/D effort (hardware development, production and operation).

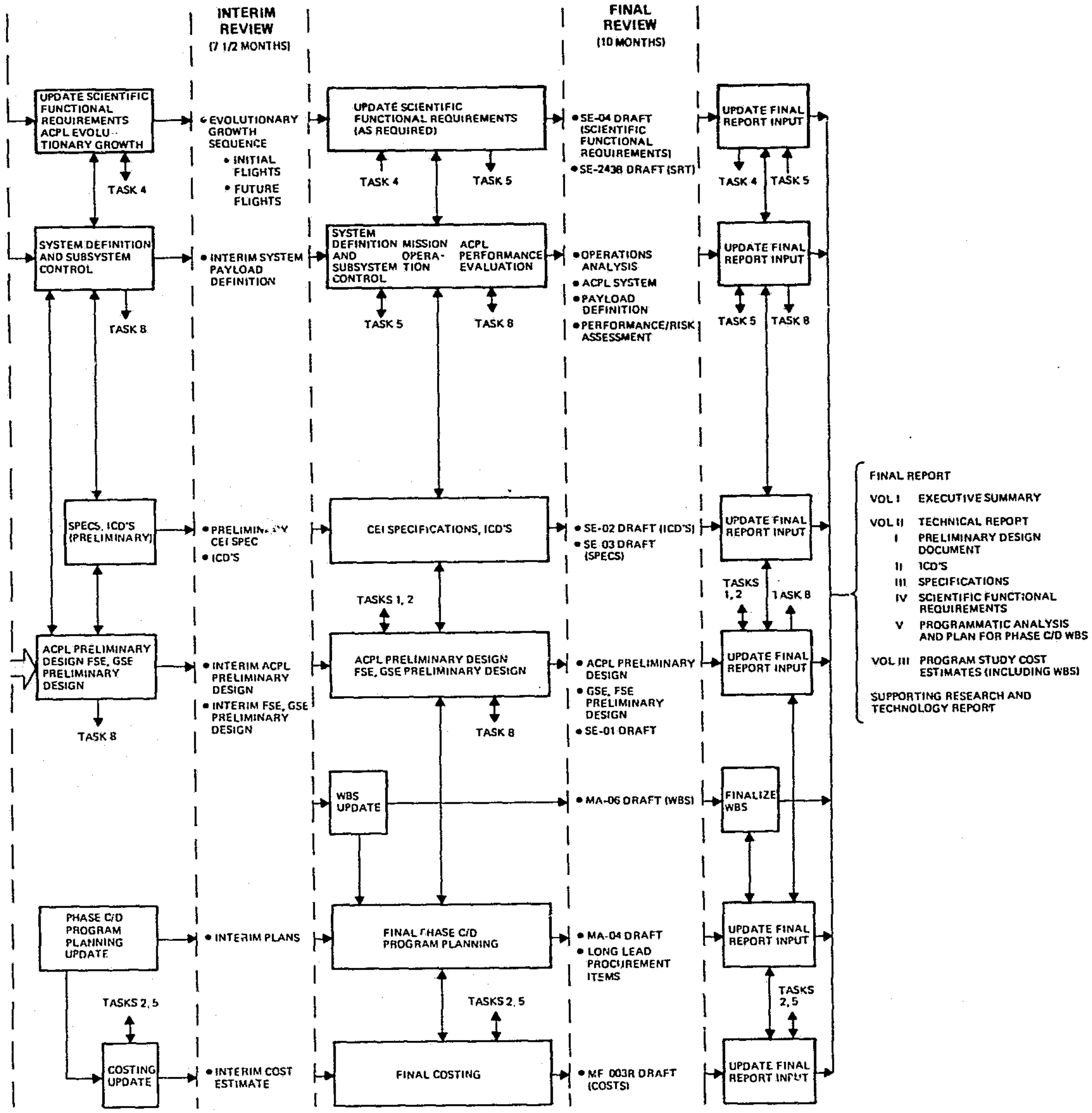
ACPL PHASE B STUDY TASKS

- TASK 1: REQUIREMENTS ANALYSES AND DEFINITION
- TASK 2: SYSTEM ANALYSES AND TRADE STUDIES
- TASK 3: SUBSYSTEM ANALYSES AND TRADE STUDIES
- TASK 4: SPECIFICATIONS AND INTERFACE CONTROL DOCUMENTS
- TASK 5: PRELIMINARY DESIGN
- TASK 6: WORK BREAKDOWN STRUCTURE AND DICTIONARY
- TASK 7: PROGRAMMATIC ANALYSES AND PLANNING FOR PHASE C/D
- TASK 8: PROJECT COSTS

TRW
SYSTEMS GROUP

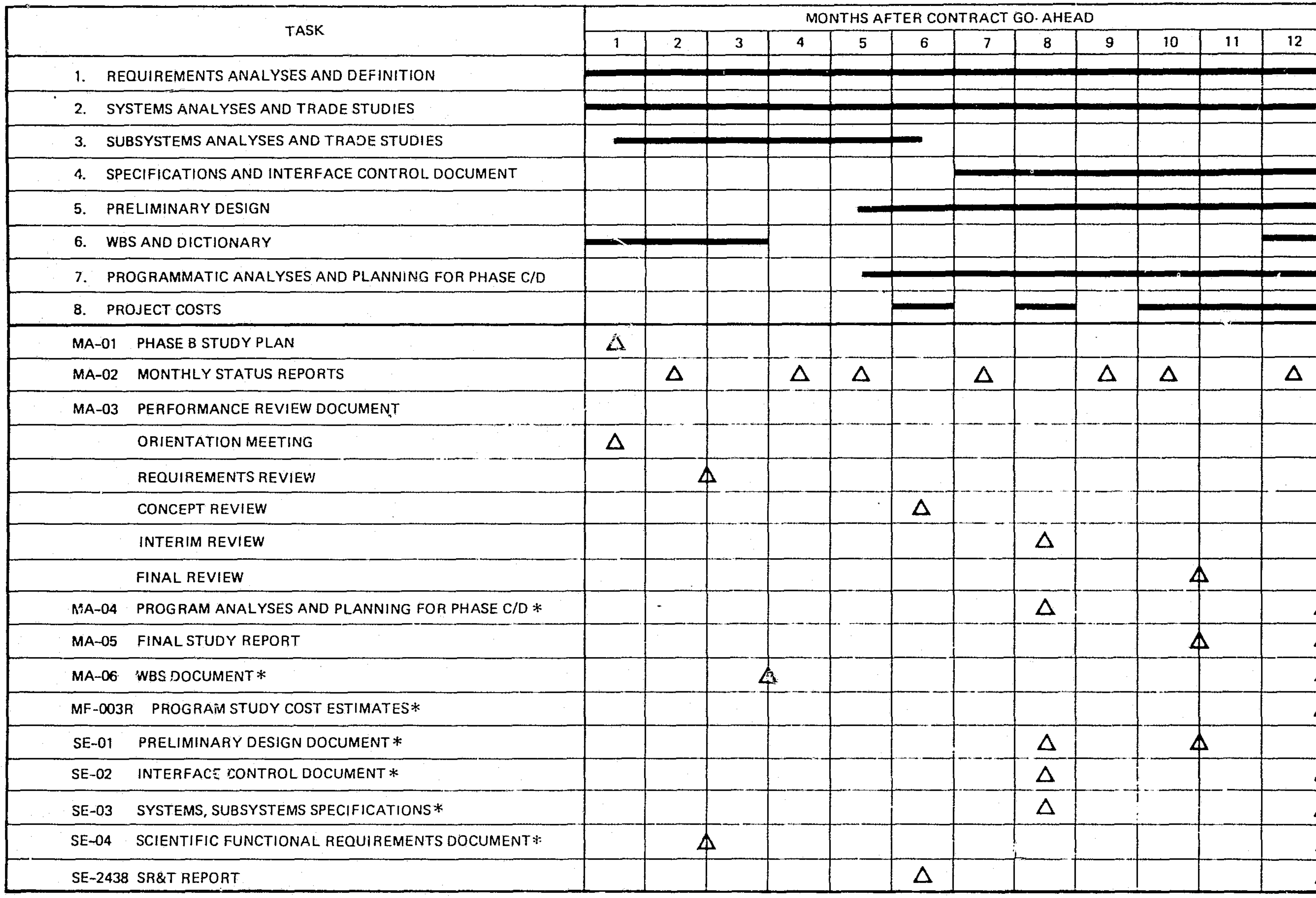


TRW
SYSTEMS GROUP



TRW SYSTEMS GROUP

This program milestone schedule shows the performance intervals of each of the eight major tasks over the twelve-month study. Also shown are the delivery dates for the contractually-required data submittals.



* PART OF FINAL REPORT

ACPL PHASE B STUDY MILESTONE SCHEDULE

SCIENTIFIC REQUIREMENTS

MARC KOLPIN

OBJECTIVES

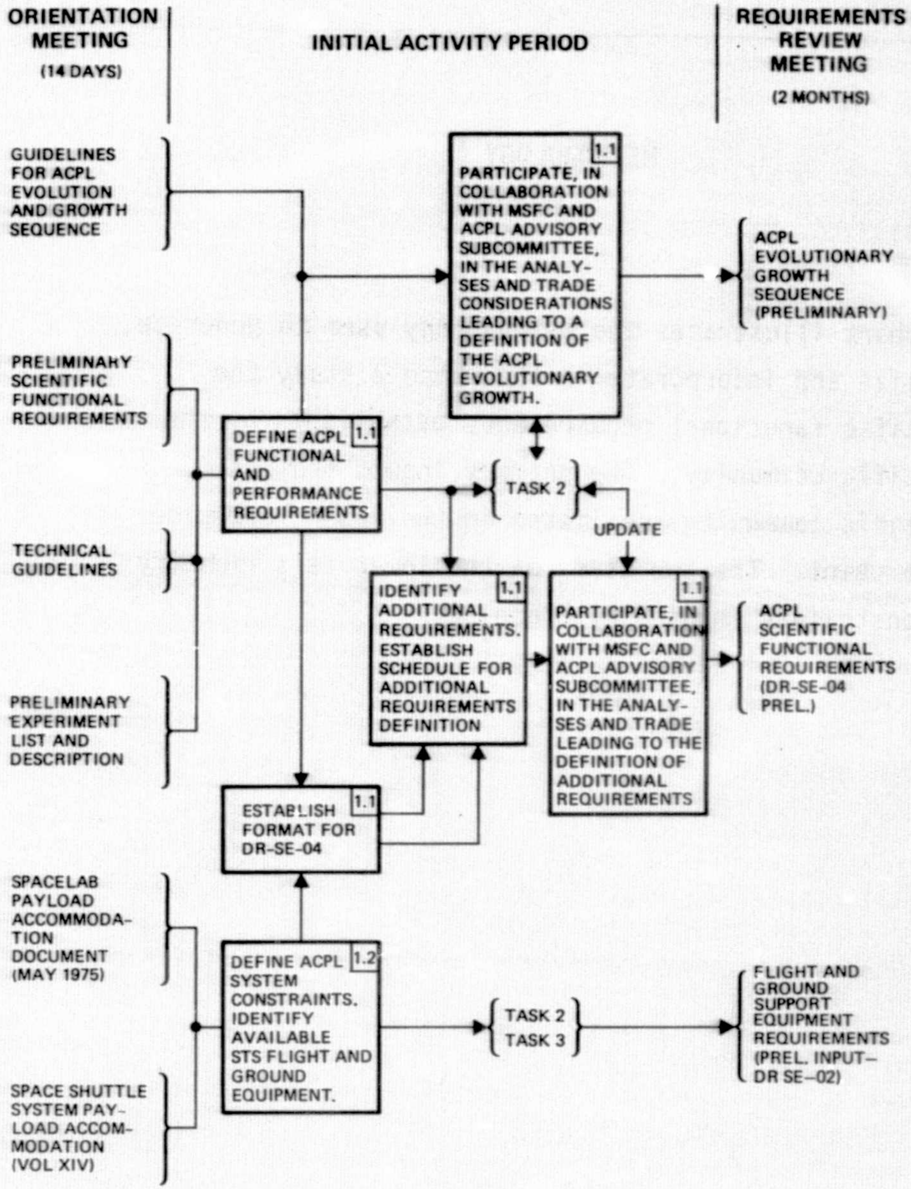
- REVIEW THE FRAMEWORK ESTABLISHED TO ALLOW FOR THE TIMELY INCORPORATION OF THE USER'S REQUIREMENTS INTO THE PHASE B STUDY

- REVIEW THE SCIENTIFIC FUNCTIONAL REQUIREMENTS WE HAVE RECEIVED AND DISCUSS SOME OF THEIR ENGINEERING IMPLICATIONS

TRW
SYSTEMS GROUP

MISSION OPERATIONS SCIENTIFIC REQUIREMENTS

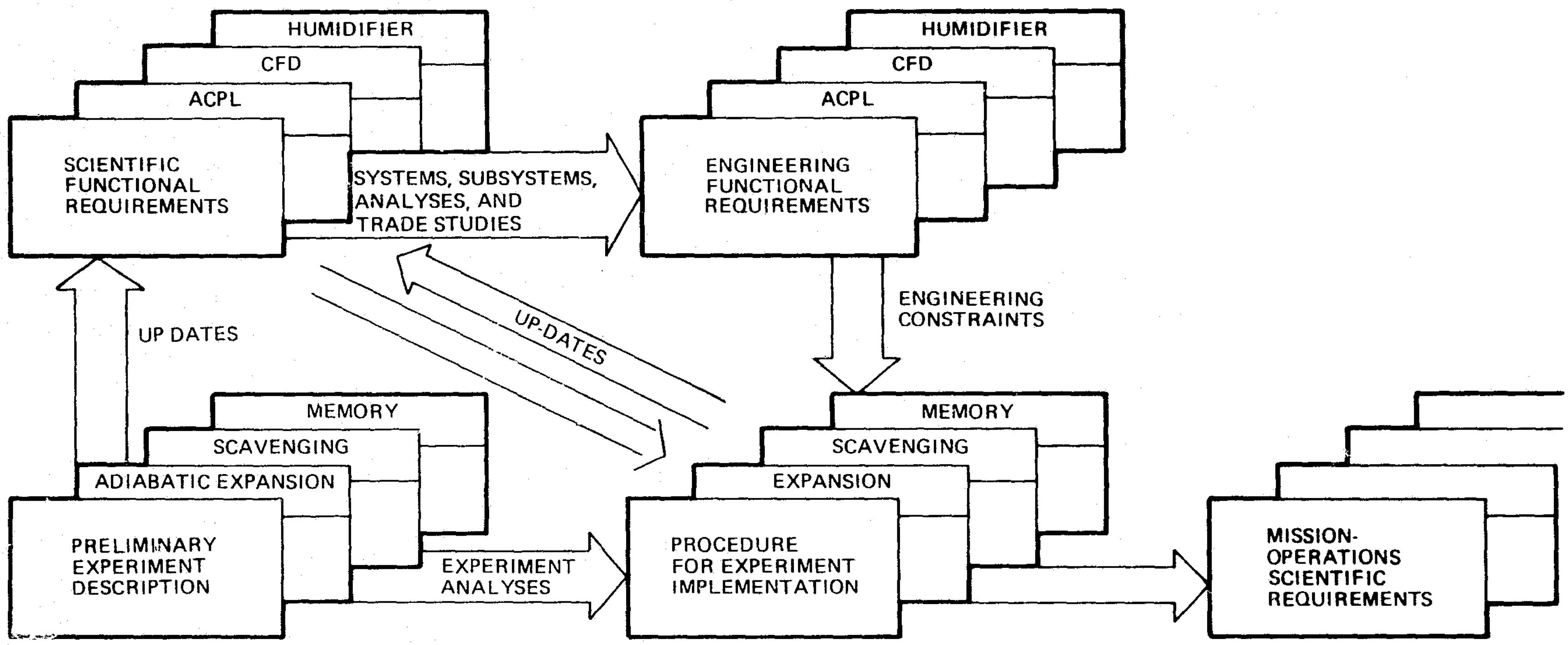
This chart illustrates the procedure leading from the scientific functional requirements and experiment descriptions to the mission operations scientific requirements. Early definition of the ACPL mission operations requirements and approval by the Spacelab program will allow for maximum flexibility for future ACPL users.



TRW
SYSTEMS GROUP

METHODOLOGY

This chart illustrates the methodology used to generate, formalize and incorporate in the Phase B study the scientific functional requirements established by the scientific community. The primary inputs from the scientific community are listed in the upper left side of the chart. The two items on the lower left identify the constraints imposed by Spacelab.



Methodology for Definition of Experimentation Implementation Procedures and Mission Operation Scientific Requirements

TRW
SYSTEMS GROUP

EVOLUTIONARY GROWTH SEQUENCE

This chart illustrates one possible evolutionary growth sequence for the ACPL. The growth sequence was constructed from the pre-planned addition of new equipment with corresponding increase in laboratory capability.

Conceptual Evolutionary Growth Sequence of the ACPL

	BASIC LABORATORY EQUIPMENT	NEAR-TERM GROWTH EQUIPMENT	LONG RANGE GROWTH EQUIPMENT
SUBSYSTEMS	THERMAL CONTROL CONTINUOUS FLOW DIFFUSION CHAMBER FLUID CONTROL EXPANSION CHAMBER OPTICS AND IMAGING HUMIDIFIER MECHANICAL CONTROL, POWER AND DATA OPTICAL PARTICLE COUNTER PARTICLE GENERATOR	DROPLET SIZE MEASUREMENT DURING CLOUD EXHAUST FROM EXPANSION CHAMBER LOW DEW POINT HUMIDIFIER IMPROVED PARTICLE GENERATOR RECOMPRESSION CAPABILITY FOR EXPANSION CHAMBER IMPROVED THERMAL CONTROL DROPLET SEPARATOR	ELECTRIC FIELD GENERATOR ICE NUCLEI CHARACTERIZER POLLUTION CONTAMINANT INJECTOR ICE NUCLEI GENERATOR STATIC DIFFUSION ICE CHAMBER DROPLET TRACE CONSTITUENT ANALYZER INFRARED MICROSCOPE PARTICLE POSITIONING SYSTEMS "IN SITU" DROP SIZE SPECTROMETER
	LEADS TO ⇩	LEADS TO ⇩	LEADS TO ⇩
EXPERIMENT CLASSES	**BASIC EXPERIMENT CAPABILITY**	**NEAR-TERM EXPERIMENT CAPABILITY**	**LONG RANGE EXPERIMENT CAPABILITY**
CONDENSATION	WARM CLOUD ADIABATIC EXPANSION EXPERIMENTS UNVENTILATED DROPLET GROWTH EXPERIMENTS	DROPLET SIZE DISTRIBUTION IN WARM CLOUD ADIABATIC EXPANSION EXPERIMENTS CONDENSATION NUCLEI MEMORY EXPERIMENTS	
COLLISION COALESCENCE PROCESSES		AITKEN NUCLEI SCAVENGING EXPERIMENTS	COLLISION AND COALESCENCE EXPERIMENTS ELECTRIC CHARGE TRANSFER EXPERIMENTS POLLUTANT SCAVENGING EXPERIMENTS
ICE FORMATION PROCESSES	SUPERCOOLED DROPLET FREEZING EXPERIMENTS ICE HOMOGENOUS NUCLEATION		ICE NUCLEATION EXPERIMENTS ICE CRYSTAL GROWTH HABIT EXPERIMENTS

TRW SYSTEMS GROUP

CONTRACTUAL SCIENTIFIC FUNCTIONAL REQUIREMENTS

This chart summarizes the original scientific functional requirements defining the Phase B study. The ACPL conceptual design presented in our proposal is based on TRW's interpretation of these requirements.

CONTRACTUAL SCIENTIFIC FUNCTIONAL REQUIREMENTS

SUBSYSTEM	PARAMETER	REQUIREMENT
PARTICLE GENERATOR	SIZE RANGE	0.001 μm TO 5 μm
	CALIBRATION OF PARTICLE COUNTERS	MUST GENERATE NUCLEI >0.1 μm DIA. WITH SUFFICIENT ACCURACY OF SIZE AND NUMBER TO PERMIT CALIBRATION.
HUMIDIFIER	RELATIVE HUMIDITY	ACCURATE DETERMINATION OF LEVEL IN CHAMBER REQUIRED (MAY BE ACCOMPLISHED BY USING SATURATED AIR AT KNOWN TEMPERATURES).
CFD CHAMBER	CONFIGURATION	THERMALLY CONTROLLED PARALLEL WICKING SURFACES SATURATED WITH WATER TO PROVIDE AN ACCURATELY DEFINED SUPERSATURATED FLUID.
EXPANSION CHAMBER	PURPOSE	PRIMARILY TO CONDUCT WARM CLOUD PROCESSES EXPERIMENTS.
	WALL TEMPERATURE	25°C TO -25°C
	PRESSURE	~1 bar TO ~333 mbar
	TEMPERATURE CONTROL	ADIABATIC EXPANSION
OPTICAL PARTICLE COUNTER	FUNCTION	PARTICLES USED IN EXPERIMENTATION TO BE MONITORED AND RECORDED PRIOR TO AND DURING THE EXPERIMENTAL PROCEDURES.
	OUTPUT	SUCH A FORM THAT IT CAN BE INTERPRETED BY THE CDMS.
OPTICS AND IMAGING	FUNCTION	TO RECORD DATA FOR EXPERIMENTATION BEING ACCOMPLISHED IN THE EXPANSION CHAMBER-
	COMPONENTS	CAMERA, LIGHT ASSEMBLIES, OPTICAL ASSEMBLIES.
	SEQUENCING	ACCOMPLISHED BY CDMS.

TRW SYSTEMS GROUP

NEW SCIENTIFIC FUNCTIONAL REQUIREMENTS

The following chart summarizes the new scientific functional requirements prepared by NASA/MFSC. These new scientific functional requirements will be reviewed and some of the engineering implications for ACPL discussed.

NEW SCIENTIFIC FUNCTIONAL REQUIREMENTS

SUBSYSTEM	PARAMETER	REQUIREMENT
PARTICLE GENERATOR	MATERIALS	NaCl, $(NH_4)_2 SO_4$, H_2SO_4, AgI, LATEX, TEFLON
	SIZE RANGE	0.001μm TO 10μm
	NUMBER DENSITY	10^7 cm^{-3} TO 10^{-1} cm^{-3}
	NaCl DISTRIBUTION	MIMIC $N=Cs^k$ such that $\int_0^{1\%} \frac{dn}{ds}\, ds = \left[\begin{array}{c} 50\ cm^{-3} \\ \text{to} \\ 1000\ cm^{-3} \end{array} \right.$ AND MAX DIA = 0.05μm
	AEROSOL STORAGE LOSS RATE	<5% IN 2 HOURS
	STORAGE OF AEROSOL FOR EXAMINATION	PROVISION FOR COLLECTION AND STORAGE OF AEROSOLS UNDER INERT GASES, ALLOWING LATER EXAMINATION BY ELECTRON MICROSCOPE.
HUMIDIFIER	MAX FLOW RATE	1000 cm^3/sec
	DEW POINT RANGE	0 TO 35°C
	RELATIVE HUMIDITY AT MAX FLOW RATE	99.995% OF SPECIFIED RELATIVE HUMIDITY
	PRESSURE CONTROL	±1.0 mb

TRW
SYSTEMS GROUP

NEW SCIENTIFIC FUNCTIONAL REQUIREMENTS

(Continued)

SUBSYSTEM	PARAMETER	REQUIREMENT
CFD CHAMBER	VOLUME	30 X 30 X 1.5 cm ±1%
	MEAN TEMPERATURE	15 - 25°C
	SUPERSATURATION RESOLUTION	0.05% TO 3%
	OPERATING POINTS	8 TO 12 POINTS ACROSS SUPERSATURATION RANGE OF SPECTRUM
	PRESSURE	NOMINAL SPACELAB CABIN PRESSURE
	VARIATION OF PRESSURE FROM SPECIFICATION MAX RATE OF PRESSURE CHANGE	$\dot{P}_{max}$ = 0.01 mb/sec
EXPANSION CHAMBER	VOLUME	3.4×10^4 cm^3 ±10%
	CLEANING	MANUAL CLEANING POSSIBLE BETWEEN EXPERIMENTS
	THERMAL CONTROL TEMPERATURE	-25°C TO 25°C
	TEMPERATURE ABS. ACCURACY	±.005°C TO 25°C
	TEMPERATURE RAMP	0 TO -0.1°C/sec
	EXPANSION DURATION	2.5 TO 90 MINUTES
	SPATIAL VARIATION OF TEMPERATURE	±0.01 TO ±0.15°C
	RIPPLE (TIME OR SPACE)	±0.02 TO ±0.15°C
	TRACKING ERROR (VS. CONTROL CURVE)	±0.02 TO ±0.1°C

TRW SYSTEMS GROUP

NEW SCIENTIFIC FUNCTIONAL REQUIREMENTS
(Continued)

SUBSYSTEM	PARAMETER	REQUIREMENT
EXPANSION CHAMBER (Continued)	DEVIATION OF CONTROL CURVE FROM SPECIFIED PROFILE	±0.05 TO ±0.005°C
	PRESSURE CONTROL	
	INITIAL PRESSURE	400 mb TO 1013 mb
	SPAN OF EXPANSION	30 mb TO 350 mb
	PRESSURE ABS. ACCURACY	±0.5 mb
	RESOLUTION (INITIAL CONDITIONS)	±0.05 mb
	RESOLUTION (DURING EXPANSION, REF. TO INITIAL PRESSURE)	±0.1 mb
	CONTROL STABILITY (INITIAL CONDITIONS)	±0.05 mb
	TRACKING ERROR (VS. CONTROL CURVE)	±0.1 mb TO ±0.2 mb
	RELATIVE HUMIDITY (PRIOR TO EXPANSION)	75 TO 99%
OPTICAL PARTICLE COUNTER	RANGE OF PARTICLE DIA.	0.3 TO 5 μm
	RANGE OF PARTICLE COUNTING RATE	10^3/sec MAX
	SAMPLE FLOW RATE	20 TO 100 cm^3/sec

TRW SYSTEMS GROUP

PRECEDING PAGE BLANK NOT FILMED

NEW SCIENTIFIC FUNCTIONAL REQUIREMENTS
(Continued)

SUBSYSTEM	PARAMETER	REQUIREMENT
OPTICS AND IMAGING	SAMPLING VOLUME	KNOWN TO WITHIN 3%
	FRAME RATE	1/sec
	PARTICLE DENSITY	10 TO 1000/cm^3
	IR AND UV RADIATION	NONE INTRODUCED INTO CHAMBER
STATIC DIFFUSION CHAMBER (OPTIONAL)	VOLUME	15 cm DIA. X 1.5cm ±1%
	THERMAL CONTROL SIDE WALL TEMP.	CONTROL TO ±0.03°C, T>0°C ±0.1°C, T<0°C
	MAX ΔT BETWEEN END PLATES	10°C
	ABSOLUTE MEAS. ACCURACY OF END PLATES	±0.05°C
	RELATIVE TEMPERATURE ACCURACY BETWEEN END PLATES	±0.05°C
	RIPPLE	±0.01°C MAX
	PRESSURE CONTROL	SPACELAB AMBIENT
	CONDENSATION	CONDENSATION ON VIEWPORTS TO BE AVOIDED
GENERAL REQUIREMENTS	MATERIAL SELECTION	USE NO MATERIALS IN TEST OR MANUFACTURE THAT WOULD CONTAMINATE EXPERIMENTS.
	TRACE GASES	NO TRACE GASES WILL BE PERMITTED IN ACPL.

NEW SCIENTIFIC FUNCTIONAL REQUIREMENTS
(Continued)

SUBSYSTEM	PARAMETER	REQUIREMENT
GENERAL REQUIREMENTS (Continued)	AEROSOL REPEATABILITY	DESIGN SHOULD PROVIDE FOR FURNISHING AEROSOL OF IDENTICAL CHARACTERISTICS TO EACH TEST CHAMBER.
	AEROSOL CHARACTERIZATION	
	PARTICLE DIAMETER MEASUREMENT ACCURACY	BETTER THAN A QUARTER DECADE.
	NUMBER DENSITY DETERMINATION	FACTOR OF 2 (BETTER AT LOWER N).

TRW SYSTEMS GROUP

PRECEDING PAGE BLANK NOT FILMED